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Gilmore et al.

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[54] **FLAT WIRE STRUCTURE AND APPARATUS AND METHOD OF MAKING SAME**

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[52] **U.S. Cl.** **57/9,** 57/139, 57/166

[51] **Int. Cl.** **D07b 1/08,** D07b 5/10

[58] **Field of Search**........57/3, 6, 9, 13, 15, 139, 144, 57/145, 156, 161, 166, 138

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[57] **ABSTRACT**

A multi-wire structure comprising an inner core member and one or more strips of flat wire wrapped helically about the core member. Each flat wire is helically twisted about its longitudinal axis by forming means to permanently deform it prior to being wrapped about the core member.

16 Claims, 6 Drawing Figures

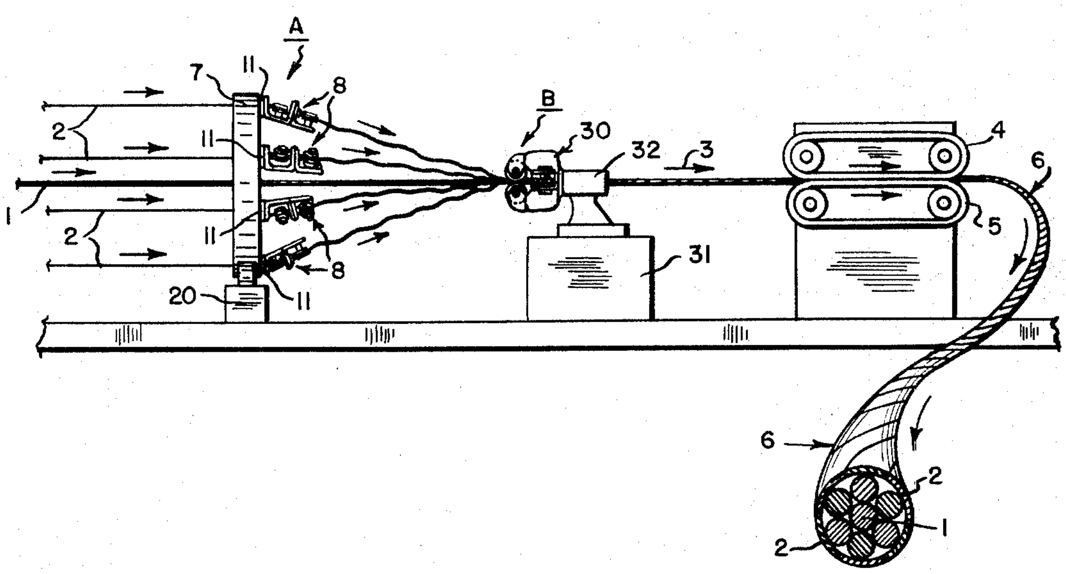


FIG. 1

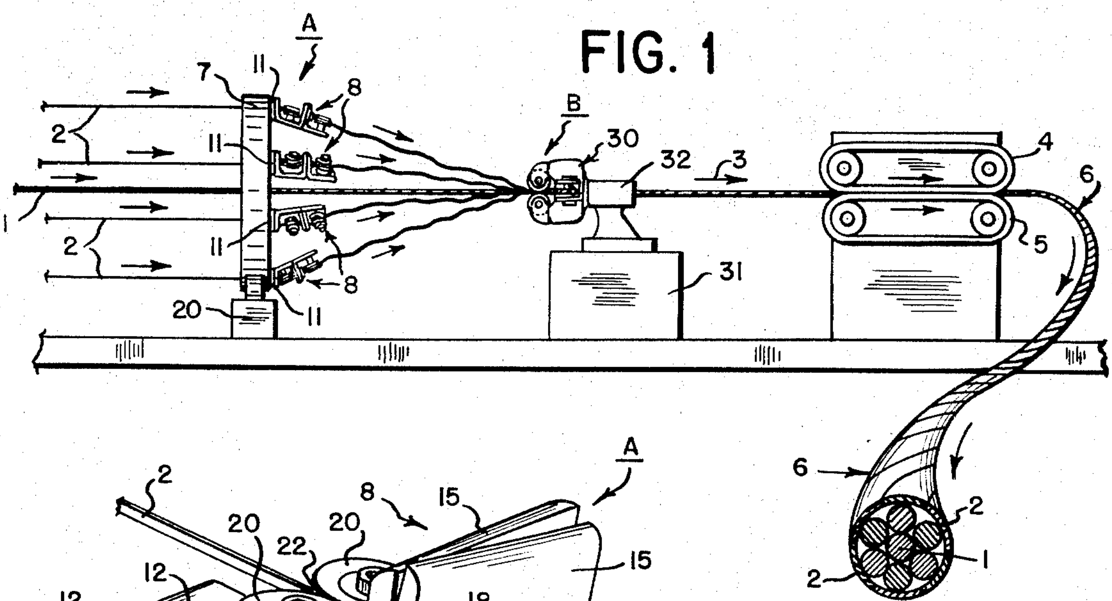
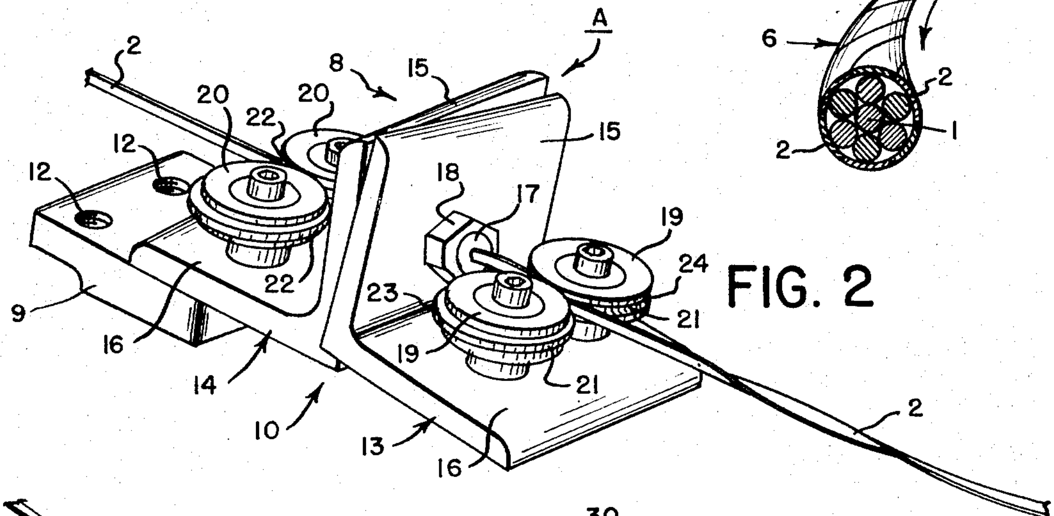


FIG. 2



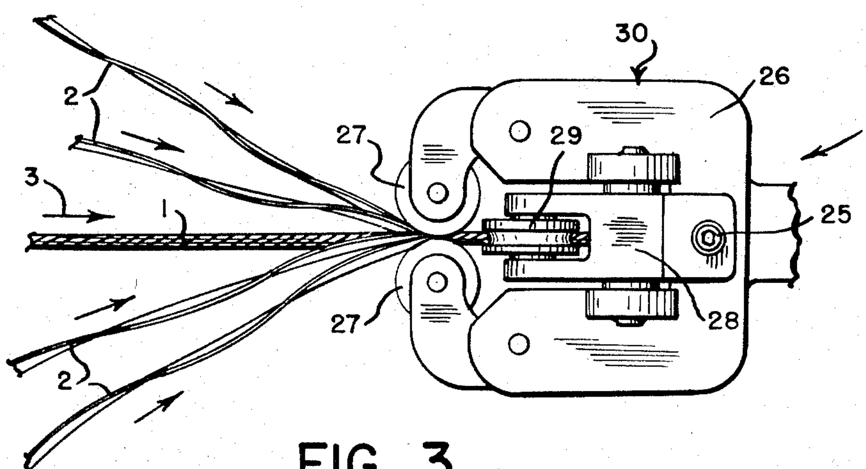


FIG. 3

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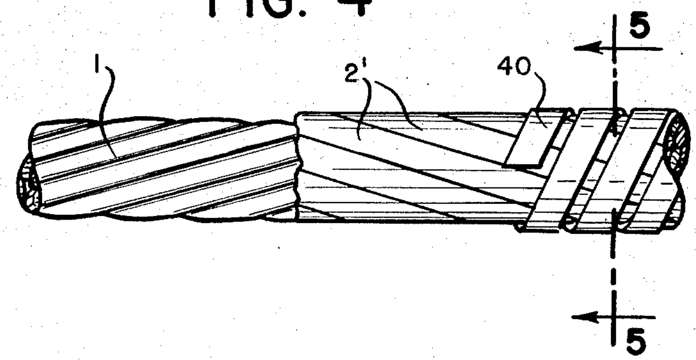
FIG. 4



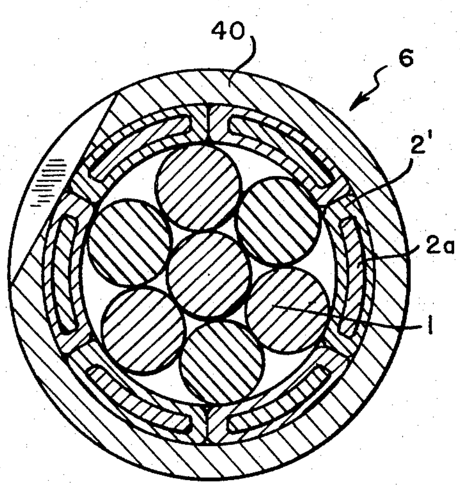


FIG. 5

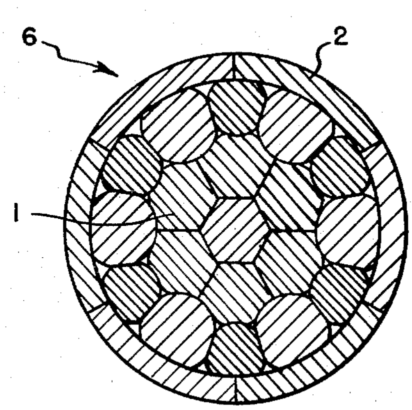


FIG. 6

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FLAT WIRE STRUCTURE AND APPARATUS AND METHOD OF MAKING SAME

BACKGROUND OF THE INVENTION

In the past, multi-wire structures in the form of strands or cables have included generally a central core member and a plurality of wires wrapped helically about the core member. For purposes of the description of the present invention, a strand is defined as a multi-wire structure having a core member comprised of a single wire or a number of single wires wrapped helically together and one or more layers of single wires wrapped helically about the core member. A cable, on the other hand, is defined as a multi-wire structure having a core member comprised of a single wire or number of helically wrapped wires and one or more layers of strands wrapped about the core member. In either case the core member is typically wrapped with wires disposed in one or more outer layers with adjacent layers being counter-wound with respect to each other for the purpose of reducing torque normally induced in the wires by tensile loading of the structure. Also the wires are usually round in cross section and are wrapped about the core member by means of conventional planetary winding or stranding equipment.

Multi-wire structures, as for example wire strands, having round wires as described above have been found to be unstable under certain conditions. For example with such strands there is a tendency for the core member to pop out when the strand is subjected to abnormal loading conditions, such as severe bending. Also, in the small diameters contemplated for strands used in certain applications, the round wires comprising the strand are extremely fine. They are therefore difficult to handle and require very delicate stranding equipment to apply. Moreover, these round wires because of their small size are subject to abrasion thus limiting the ability of the strand in which they are used to withstand normal wear and tear in service.

If flat wires are used in place of the round wires for wrapping about the core member, the above problems are substantially eliminated. Thus a strand comprising flat wires has good inherent stability with little or no tendency for the core member to pop when the strand is subjected to bending. Also, several of the round wires may advantageously be replaced with a single flat wire having a width corresponding to the combined width of the replaced round wires. Thus, for instance, a layer comprising say twelve round wires may be replaced with a layer comprising only four flat wires with each flat wire covering the same amount of strand surface as three of the round wires. In the example given, the substituted flat wire is appreciably easier to handle than the three smaller round wires. Furthermore, because of its greater mass, a single flat wire is better able to withstand abrasion and other forms of wear and tear than the smaller round wires.

In wrapping flat wire about the core member, several problems have been encountered which heretofore have prevented, as a practical matter, widespread acceptance and use of this type of wire structure. For instance, flat wires must of necessity, be applied to the core member in a nonplanetary manner. This restriction results in an extremely wild construction in which the flat wires tend to unwind, at least partially, from the core member at the completion of the wrapping operation when the finished wire structure is removed from the capstan or other restraining means. The tendency to unwind exhibited by the flat wires is due primarily to residual stress in each flat wire which cannot be effectively eliminated with nonplanetary stranding equipment. Moreover, when the flat wires are made of high yield strength material which normally offers strong resistance to the type of bending which must occur in order to wrap the flat wires about the core member, the effects of residual stress are even more pronounced.

Another problem encountered in the fabrication of multi-wire structures having flat wires is the difficulty of symetrically containing the core member within the outer layer of flat wires during the wrapping operation.

SUMMARY OF THE INVENTION

In accordance with the teachings of the present invention there is provided a multi-wire structure in which torque induced by tensile loading is minimized. In construction, the multi-wire structure which may be either a strand or cable generally includes an inner core member and one or more strips of flat wire disposed helically about the core member. Advantageously, a plurality of strips of flat wire are wrapped about the core member to form a single layer of the wire structure.

In order to eliminate residual stress and thus reduce the amount of torque induced by tensile loading of the wire structure in service, each flat wire is first individually twisted into a helix about its longitudinal axis and thereafter wrapped helically about the core member in the same direction as the direction of the previously formed helix. Also, the lay of each layer of helically twisted flat wire is opposite in direction to the lay of the underlying layer.

To produce the multi-wire structure in accordance with the teachings of the present invention, the core member is moved in a longitudinal direction and each strip of flat wire is first twisted and then moved rotationally about the moving core member. After being initially wrapped about the core member by this rotational movement each helically twisted strip is pressed tightly about the core member. Advantageously, each helically twisted flat wire is also compacted about the core member.

For the purpose of imparting a helical twist to each of the strips of flat wire, forming means are provided wherein each strip is subjected to a combined twisting and deforming action prior to being wrapped about the core member. Each forming means includes a frame and strip guiding and restraining means mounted on the frame for directing the strip of flat wire longitudinally through the forming means while at the same time holding spaced apart portions of the strip in preselected angular positions. In construction, the guiding and restraining means includes two spaced apart pairs of strip holding rollers. The rollers of each pair are positioned with respect to each other to define opposed strip holding surfaces which engage opposite sides of the strip; and the portion of the strip held by one pair of rollers is held in a plane which forms an angle with respect to the plane in which the other portion is held. With this arrangement, the section of flat wire extending between the two pairs of strip holding rollers is twisted until it exceeds its yield point with the result that a permanent helical twist is imparted to the strip.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagrammatic illustration of the apparatus used to produce the flat wire structure of the present invention showing also a view of the wire structure in cross section.

FIG. 2 is a perspective view of the apparatus used to impart a helical twist to each strip of flat wire.

FIG. 3 is an elevation view of the apparatus used to form the helically twisted strips of flat wire tightly about the core member.

FIG. 4 is a fragmentary elevation view, partly broken away, of a modified embodiment of the new multi-wire structure with an outer wrapping of flat wire counterwound with respect to the helically twisted strips of flat wire immediately therebeneath.

FIG. 5 is a cross-sectional view taken along the lines 5—5 of FIG. 4.

FIG. 6 is a cross-sectional view of a modified embodiment of the invention in which a pre-compacted core member is used.

DETAILED DESCRIPTION OF THE INVENTION

With reference to FIG. 1, the apparatus includes a pre-twisting and deforming station A, and a wrapping station B. The apparatus shown in FIG. 1 is used for making a multi-wire strand structure. A core member 1 and plurality of strips of flat wire 2 are drawn through the pre-twisting and deforming station A wherein each strip is given a permanent helical twist about its longitudinal axis. The core member and strips are then fed through the wrapping station B where the latter are helically wrapped tightly about the core element.

Means located downstream of the wrapping station B are provided for moving the core member in the longitudinal path indicated by the arrow 3. As shown, this means includes a pair of driven endless belts 4 and 5 which frictionally engage either side of the completed wire strand structure 6. With this arrangement each strip of flat wire is also advantageously advanced through stations A and B under the moving force of endless belts 4 and 5. Each strip of flat wire and the core member is fed from suitable supply spools (not shown) located upstream of the pre-twisting and deforming station A.

As shown in FIG. 1, the core member comprises a 1 × 7 stranded construction of round wires. These wires are made of high tensile strength material such as steel while each strip 2 of flat wire is made of high yield strength material in the sense that it resists bending and will not easily take a permanent set. An example of such material is steel. It should be noted that the core element may be comprised of different numbers of wires, stranded or not, or, if desired, may simple be constructed of a single solid wire made of high tensile strength material such as steel. Also, in the event the core member is multi-wired, it may be either precompacted prior to wrapping the strips of flat wire thereabout or non-compacted depending on the particular application. A pre-compacted strand core construction is, by way of example, shown in FIG. 6 and may be constructed in accordance with the teachings of my U.S. Pat. No. 3,234,722.

In construction, the pre-twisting and deforming station includes means for rotating each strip of flat wire about the core member as it is being advanced toward the wrapping station. In the presently preferred embodiment of the invention, this means includes a circular support 7 through which the strips 2 first pass after leaving their respective supply spools. The circular support is mounted for rotation about an axis coincident with the moving core member 1 and, as shown in FIG. 1, the strips 2 pass through the circular support at points spaced evenly about its circumference so that the strips 2 encircle the core member in radially spaced relationship thereto. Suitable drive means, indicated diagrammatically by reference numeral 20 are provided for rotating the circular support.

As shown in FIG. 1, the pre-twisting and deforming station also includes a plurality of stationary forming members 8 through which the flat wires 2 are fed after passing through the circular support 7. The forming members 8 are fixedly mounted on the circular support 7 with one forming member located along the path of feeding of each strip of flat wire. The forming members 8 are stationary in the sense that they have no planetary motion about the core element.

For the purpose of mounting each forming member 8 on the circular support, a rigid coupling 9 is provided. One end of the coupling 9 is suitably secured to the forming member 8 such as by welding. The other end of the coupling is attached to a mounting post 11 on the circular support 7 provided for this purpose. As shown in FIG. 2, bolt holes 12 are provided in the coupling for bolting it to the appropriate mounting post.

Each forming member includes a frame, indicated generally by reference numeral 10, and strip guiding and restraining means mounted on the frame for directing the strip of flat wire longitudinally through the forming member while at the same time holding spaced apart portions of the strip in pre-selected angular positions. In the construction shown in the drawings, the frame 10 comprises two angle brackets 13 and 14 each of which includes a back plate 15 and support plate 16 extending in a direction perpendicular to the back plate 15. Angle brackets 13 and 14 are held together in back-to-back relationship with the abutting back plates 15 extending in a same direction and the support plates 16 extending in opposite directions. Anchorage bolt 17 extending through the abutting back plates 15 and lock nut 18 are provided for this purpose. As shown, the anchorage bolt 17 is drilled out to provide an opening for the purpose of permitting free passage of the strip 2 of flat wire. With the above construction, the angular position of angle bracket 13 is adjustable with respect to the angular position of angle bracket 14.

For purposes of imparting a helical twist to each strip of flat wire as it is drawn longitudinally through its respective forming member 8, the guiding and restraining means holds one portion of the flat wire in a plane forming an angle with respect to the plane in which the other portion is held. In the construction shown in the drawings, the guiding and restraining means includes two spaced apart pairs of strip holding rollers 19 and 20. The rollers 19 are rotatably mounted on support plate 16 of angle bracket 13 which the rollers 20 are rotatably mounted on support plate 16 of angle bracket 14.

The rollers of each pair are positioned with respect to each other to define opposed strip holding surfaces 21 and 22 which engage opposite sides of the flat wire 2 in such a manner as to permit longitudinal movement thereof between these surfaces while at the same time holding the portion of flat wire **2** passing therebetween against rotation about its longitudinal axis. In the presently preferred embodiment of the invention, the strip holding surfaces are defined by mating tongue **23** and groove **24** surfaces extending around the periphery of rollers **19** and **20**. The tongue **23** fits within groove **24** to hold the portion of flat wire **2** passing therebetween against rotation but not tightly enough to impede longitudinal movement through the forming member. To properly hold the flat wire **2** in this manner, the width of groove **24** is advantageously made approximately equal to the width of the strip of flat wire.

As mentioned above, the strip holding rollers **19** hold the portion of flat wire **2** passing therebetween in a plane which forms an angle with respect to the plane in which the strip holding rollers **20** hold the flat wire. With this arrangement, a torsional stress or twisting action is imparted to the section of flat wire extending between the nip of rollers **19** and the nip of rollers **20** as the strip of flat wire is pulled longitudinally. When the amount of stress thus imposed exceeds the yield point of the material from which the flat wire is constructed, the strip of flat wire assumes a permanent deformation in the form of a helix about its longitudinal axis. The amount of helical twist produced in the strip as it is drawn through the forming member is controlled by adjusting the relative angular position of the strip holding rollers **19** and **20**. As shown in FIG. **2**, this may be accomplished by simply adjusting the relative angular position of angle brackets **13** and **14**.

In some situations, it may be desired to form more than one complete twist in the wire. In such a situation, the pairs of rollers need, of course, only be rotated the angular amount necessary for forming the fractional twist greater than the number of complete twists desired. For example, if two and one fourth twists are desired, it is only necessary to rotate the pairs of rollers into planes disposed at **90°** relative to each other and the first two twists may be produced by hand before inserting the wire into the bite of the second rollers. Going one step further, if one or more complete twists are desired without any fractional twisting, all twisting can then be done by hand during the initial feeding of the wire through the rollers and the rollers will be set in straight alignment with each other. Thus, the portion of the wire held by the first pair of rollers will be held in a plane common with the plane in which the portion of the wire passing through the second pair of rollers is held.

At the wrapping station B, the flat wires **2** are wrapped helically in side-by-side relationship about the core member **1** to form a single layer of the strand. As shown most clearly in FIG. **3**, the wrapping station B includes a closing die **30** comprising a first U-shaped frame member **26** having a pair of grooved pressure rolls **27** between which the core member **1** and flat wires **2** are initially drawn. A second pair of grooved pressure rolls **29** between which the core member and flat wires next pass is mounted on a second U-shaped frame member **28** extending in a direction perpendicular to the frame member **26**. The frame members **26** and **28** are suitably connected together by bolt means **25** and this assembly is mounted on a support member **31** by means of an apertured sleeve **32** through which the formed multi-wire strand structure finally passes. By properly adjusting the pressure rolls **27** and **29**, the flat wires **2** can be compacted about the core member **1** while passing through the closing die.

The closing die acts to direct each pre-twisted strip of flat wire from the pretwisting and deforming station to the wrapping station. The path of each wire converges toward a predetermined point along the path of movement of the core member; and, at this point, each pretwisted strip is wrapped helically in adjacent turns about the core member. Advantageously, this point is located as close as possible to the mouth of the closing die so that there is no difficulty in symetrically containing the core member within the layer of helically wrapped strips before it enters the closing die.

After being wrapped about the core member but before passing through the closing die **30**, each pretwisted flat wire is disposed flatly in a relatively tight helical arrangement about the core member. The strips are disposed flatly in the sense that they remain substantially planar in shape with the side which contacts the core member forming a tangent therewith. Subsequent feeding through the closing die **30** acts to form the finished strand by deforming each strip of flat wire generally to the curvature of the core member. Thus, as shown in FIG. **1**, after passing through the closing die, each strip has a slight curvature in its widthwise direction. Advantageously, the flat wires are also compacted about the core member as they are fed through the closing die.

The direction in which each pre-twisted strip of flat wire is wrapped is the same as the direction of the helical twist in each strip while the lay of each strip is advantageously opposite in direction to the lay of the underlying layer of the strand. With this arrangement torque induced in the completed structure by tensile loading is minimized.

It should be pointed out that during the wrapping process, each helically twisted flat wire is actually deformed into a helical configuration apart from its preformed helical twist so that it will lay helically about the core element. That is, the helical convolutions imparted to each flat wire by wrapping it helically around the core member together define a central bore through which the core element extends.

The wire structure of the present invention has several advantages over wire structures having an outer layer of round wires. Due primarily to the preformed helical twist, each strip of flat wire is able to be wrapped about the core member substantially free of residual stress. This, in turn, provides the multi-wire structure of the present invention with more complete resistance to torque induced from tensile loading and, in particular, from the undesirable effects flowing therefrom. Thus, the wire structure exhibits substantially less tendency to throw itself into coils and the strips of flat wire do not tend to unwind from the core member either at the completion of the wrapping operation or when in service in the field. Moreover, the core member is contained securely within the outer wrapping of flat wires and thus, it is less likely to pop out when the wire structure is subjected to bending. Also, it will be recognized that the above advantages have been achieved without sacrificing the tensile strength of the final structure.

The wire structure produced in accordance with the teachings of the present invention has many applications. For instance, the strand structure is particularly well suited for use as an anchor line in oceangraphic mooring applications. It will be realized that when the strand is used for this purpose, it is periodically loaded and released by underwater current and wave action and as a consequence has a tendency to throw itself into coils due to the torsion induced from this type of loading. However, when the strand of the present invention is used as the anchor line, this problem is substantially avoided.

Another application for which the wire structure of the present invention is particularly well suited can be more readily understood by references to the embodiment of the present invention illustrated in FIGS. **4** and **5**. In this embodiment, the wire structure of the present invention is intended for use as a combined tow line and antenna for air craft as described in my U.S. Pat. No. 3,206,543. Because the structure shown in FIGS. **4** and **5** is used to transmit and receive radio frequency signals, the strips **2'** of flat wire are made of electrically conductive metal such as copper and, as shown in FIG. **5**, each strip **2'** is provided with a reinforced core **2***a*. The core **2***a* is made of high yield strength material to preserve strength in the structure. The strips **2'** are pretwisted and wrapped helically about the core member **1** in side-by-side relationship in the same manner as are the strips **2** described in connection with FIGS. **1** to **3**. Also, the strips **2'** may be compacted about the core member.

The wire structure shown in FIGS. **4** and **5** is further provided with an outer wrapping consisting of a flat wire **40** also made of electrically conductive metal such as copper. To preserve flexibility in the structure, the strip **40** is wrapped helically in spaced turns about the strips **2'** in a direction opposite thereto. The strip **40** is also compacted in place about strips **2'**. This compacting advantageously reduces the diameter of the wire structure to result in partially filling and bridging the gaps between the adjacent turns in the strip **40**. This, in turn, reduces the tendency of current to follow the helix of the outer strip **40** and hence produces a relatively linear flow of radio frequency energy through the cable with resultant high transmission efficiency.

We claim:

1. A multi-wire structure comprising:

a. a core member; and

b. at least one strip of flat wire wrapped helically about the core member and having a preformed permanent helical twist about its longitudinal axis apart from the helical configuration assumed thereby when wrapped about the core member, said helical twist being in the direction of the helical wrap.

2. The wire structure according to claim **1** including:

a. a plurality of the strips of flat wire wrapped helically in side-by-side relationship about the core member to form a single layer of the wire structure.

3. The wire structure according to claim **2** wherein:

a. each strip of flat wire has a permanent deformation in the form of helical convolutions about the core member.

4. The wire structure according to claim **3** wherein:

a. each strip of flat wire is made of a high yield strength material.

5. The wire structure according to claim **4** wherein:

a. the strips of flat wire are radially compressed in place about the core member.

6. The wire structure according to claim **4** wherein:

a. each strip of flat wire is made of copper having a reinforced core of high yield strength material.

7. The wire structure according to claim **6** further comprising:

a. an outer strip of flat copper wire wrapped helically in spaced turns about the next underlying layer in a direction opposite thereto, said outer strip being compacted about the next underlying layer of the wire structure.

8. A method for manufacturing a multi-wire structure having an inner core member and an outer layer of helically wrapped flat wires comprising the steps of:

a. subjecting at least one strip of flat wire individually to a twisting action torsionally stressing it beyond its yield point to thereby permanently deform said strip of wire into a helically twisted configuration about its longitudinal axis; and

b. wrapping said helically twisted wire in helical relationship about said core member while continuously maintaining said original helically twisted configuration, said helical wrapping being in the same direction as the helical twist.

9. The method according to claim **8** wherein:

a. a plurality of said helically twisted flat wires are wrapped about the core member to form a single layer of the wire structure.

10. The method according to claim **9** further comprising the step of:

a. compacting each helically twisted wire tightly about the core member.

11. Apparatus for wrapping at least one strip of flat wire about a core member to produce a multi-wire structure comprising:

a. means for moving the core member in one direction along a predetermined path;

b. pretwisting and deforming means for imparting to each strip of flat wire a permanent helical pretwist in one direction about its longitudinal axis apart from the helical configuration of the flat wire about said core member, said pretwisting and deforming means comprising a plurality of stationary forming members each of which includes:

1. a frame, and
2. two strip holding and restraining means mounted on the frame at spaced intervals for directing the strip of flat wire longitudinally while at the same time holding spaced apart portions thereof against rotation with one of said portions held in a plane relative to the plane in which the other of said portions is held to maintain a twist in the wire disposed between the two portions, said strip holding and restraining means being mounted on said frame for angular adjustment with respect to each other;

c. converging means for directing each pretwisted strip of flat wire along a path converging towards a predetermined point along the path of movement of the core member; and

d. rotating means for rotating each pretwisted strip of flat wire about the core member as it is being advanced toward said point to helically wrap each strip of flat wire about the moving core member at said point.

12. Apparatus as set forth in claim **11** for wrapping a plurality of strips of flat wire about the core member to form a single layer of the wire structure wherein:

a. said means for rotating each pretwisted strip of flat wire about the core member comprises a rotatable support disposed concentrically about the moving core member and through which the strips of flat wire pass at predetermined positions spaced thereabout in radially spaced relationship to the moving core member;

b. said means for directing each pretwisted strip of flat wire along a path converging towards said predetermined point comprises a closing die located at said predetermined point through which the core member and flat wires pass as the latter are being helically wrapped about the moving core member.

13. Apparatus according to claim **12** wherein:

a. said strip holding and restraining means comprises two spaced apart pairs of strip holding rollers, one pair of rollers being mounted for rotation about parallel axes disposed at an angle to the axes of rotation of the other pair of rollers.

14. Apparatus for deforming a strip of flat wire into a permanent helical twist about its longitudinal axis comprising:

a. a frame having a pair of angular brackets each of which includes:

1. a back plate;

2. a support plate extending at an angle to the back plate, said angle brackets being held in back-to-back relationship for angular adjustment with respect to each other with the back plates of each extending in the same direction and the support plates of each extending in opposite directions; and

3. an opening extending through the back plates for permitting free passage of the strip of flat wire; and

b. strip holding and restraining means mounted on the frame for directing the strip of flat wire longitudinally while at the same time holding spaced apart portions of the strip against rotation with one of said portions held in a plane relative to the plane in which the other of said portions is held to maintain a twist in a wire between the two portions, said strip holding and restraining means comprises two spaced apart pairs of strip holding rollers, each pair of rollers being mounted on one of said support plates with one pair of rollers being mounted for rotation about parallel axes disposed at an angle to the axes of rotation of the other pair of rollers, the rollers of each pair being positioned with respect to each other to define opposed strip holding surfaces engaging opposite sides of the strip of flat wire passing therebetween.

15. Apparatus according to claim **14** wherein the strip holding surfaces of each pair of rollers are defined by mating tongue and groove surfaces extending around the periphery of the rollers of each pair.

16. Apparatus according to claim **15** wherein said groove has a width approximately equal to the width of the strip of flat wire.

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