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MULTISTRAND CABLE

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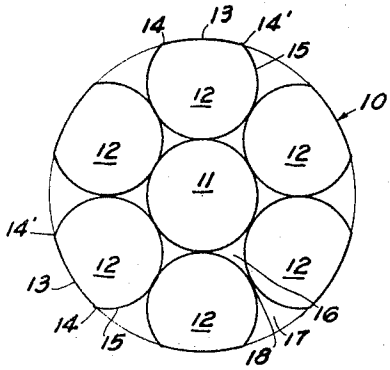


Fig. 1

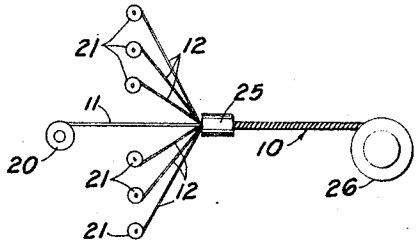


Fig. 2

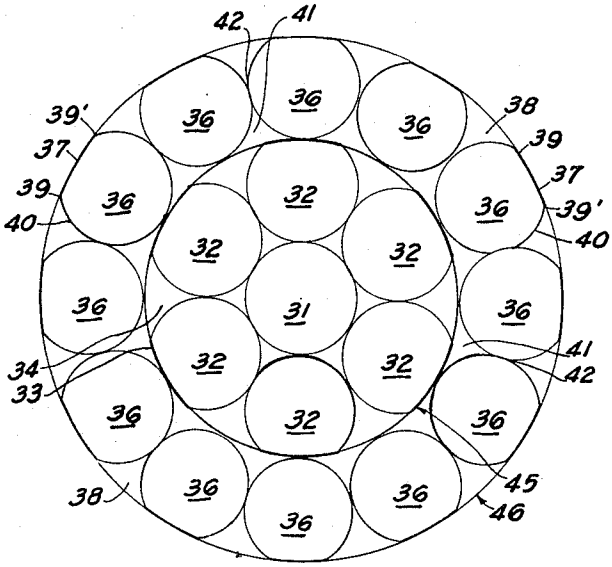


Fig. 3

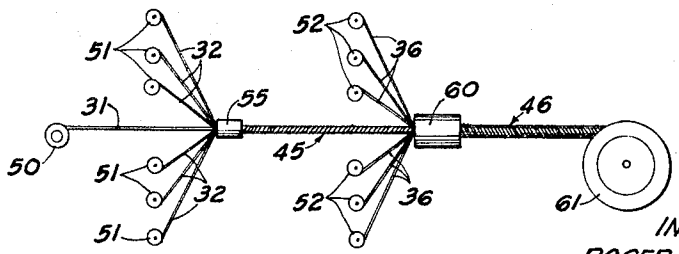


Fig. 4

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MULTISTRAND CABLE

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ABSTRACT OF THE DISCLOSURE

What is disclosed herein is a multistrand cable which avoids the spiralling and other undesirable characteristics of a conventional uncompacted cable and which avoids the lack of flexibility and other undesirable characteristics of a conventional compact cable. Specifically, the cable disclosed herein is a multistrand cable having a core strand which is of substantially circular cross-section and having a plurality of layer strands, each of which is of substantially circular cross-section and each of which has a relatively flattened region along its length that is limited in width to that width which can be achieved by deforming without causing the cable to have the undesirable characteristics of a conventional compact cable.

The present invention relates to multistrand cable. More particularly, the present invention relates to multistrand electrical cable wherein imprinting of the insulating cover and any tendency to spiral have been substantially eliminated while retaining good overall physical properties including flexibility.

The usual method presently employed to form multistrand electrical cable involves helically stranding a plurality of individual wire strands about a central core strand in one or more layers without deformation of any of the strands. This type of cable is generally referred to as conventional uncompacted cable. The resulting cross-section of the cable comprises a core strand surrounded by one or more concentric arrays of individual strands wherein each strand including the core strand is of circular cross-sectional configuration. After stranding the cable is normally covered with a suitable insulating material such as neoprene or a polyolefin by an extrusion-coating process.

Several problems exist with cable formed in this manner. First, since no effort is made to reduce the cable diameter a maximum amount of insulating material is necessary to provide a cover for the cable. This amount of insulating material is further increased due to the superficial valleys on the cable which are created by the individual strands of circular cross-section forming the outermost concentric array. Second, the stranding operation does not form a particularly tight-stranded cable. As a result the extrusion-coating process, which operates at relatively high pressures, forces insulating material into the internal interstices between the individual strands of the cable thereby causing what is commonly referred to as "imprinting" in the resultant insulating cover. Third, relatively long lengths of the cable have a pronounced tendency to assume an elongated spiral configuration. This spiralling in the cable is caused by kinks in the core strand or in one or more of the layer strands. It is also caused by unequal tension placed on the individual strands as a result of the stranding operation.

In an effort to overcome these problems it has previously been proposed to highly compress the stranded cable to the extent that the internal interstices are eliminated and the valleys are reduced to a minimum in size. This has been accomplished by passing the cable immediately after being stranded through a high compression die. The

resulting cross-section of the cable comprises the usual core strand surrounded by one or more concentric arrays of individual strands; however, each strand including the core strand has been deformed to the extent that its original cross-section has been altered to resemble a polygonal configuration. All of these deformed strands nest together to form a substantially continuous cross-sectional surface wherein only lines of juncture between the individual strands remain in place of the interstices. From a practical view, there is a limit on the size of cables which may be compressed in this manner since high pressures are required for the compressing operation and it becomes increasingly difficult to achieve the necessary pressures as the diameter of the cable is increased.

Stranded cable which has been compressed in this manner is generally referred to as "compact" cable. Because of the compactness of the cable the extruded insulating cover does not suffer from imprinting and also less insulating material is necessary to completely cover the cable due to its reduced diameter. Moreover, the compressive forces required to produce compact cable essentially remove any kinks which may be in the individual strands and substantially equalize the tension forces among the strands thus eliminating the spiralling characteristic which is present in the completely uncompacted cable.

There do exist some serious drawbacks in forming compact cable. First, the required compression forces are so high that the stranded cable is subject to frequent breakage as it is drawn through the compression die, particularly with cables of relatively large diameters. Second, a very large drawing force is required thus increasing power consumption. Third, and probably most important, the metal strands become cold worked as they pass through the compression die and consequently their physical properties are altered. By far the most important effect on physical properties is the loss in flexibility and elongation when considering that the product comprises electrical cable.

Therefore, in accordance with the present invention there is provided a multistrand electrical cable which does not suffer from the spiralling characteristics nor imprinting of the insulating cover as are present in the conventional uncompacted cable yet substantially has the desirable physical properties such as flexibility and elongation which are not present in compact cable.

Briefly described, the stranded electrical cable of the present invention in its most simple construction is formed by helically stranding a plurality of individual wire strands about a central core strand in a concentric array forming a single layer. Thereafter the stranded product is passed through a sizing die to substantially deform or flatten only the outermost surface of the single-layered cable. This degree of deformation has been found to be sufficient to substantially eliminate the internal stresses set up within the strands during the stranding operation which cause spiralling. The resulting cable comprises a core strand, having a substantially circular cross-sectional configuration, surrounded by a single concentric array of helically wound individual strands whose surface portions corresponding to and forming the outermost surface of the cable have been flattened. The remaining surface portions of the individual strands retain their smoothly curved configurations.

Thus, another readily apparent feature of the present invention as compared to the conventional uncompacted cable is that less insulating material is required due to the reduction in size of the valleys on the surface of the cable and a reduced effective diameter of the cable. In addition, as compared to the formation of compact cable, the formation of the cable of the present invention requires much less compression and drawing force thereby

significantly decreasing potential breakage of the stranded cable as it passes through the sizing die. Of course, larger diameter cables are also capable of being formed in accordance with the present invention as a result of the lower forces required.

These and other features and objects of the present invention will become more apparent from the following discussion and the accompanying drawings wherein:

FIGURE 1 is a cross-sectional view of the stranded electrical cable comprising the present invention in its most simple construction.

FIGURE 2 is a schematic view illustrating the manner in which the cable shown in FIGURE 1 is formed.

FIGURE 3 is a cross-sectional view of another embodiment of the stranded electrical cable comprising the present invention wherein two concentric arrays of individual strands are provided around a central core strand.

FIGURE 4 is a schematic view illustrating the manner in which the cable shown in FIGURE 3 is formed.

With reference to FIGURE 1, there is shown one embodiment of the multistrand electrical cable, generally designated by numeral **10**, which includes a core strand **11** surrounded by a single concentric layer of helically wound strands **12** which are in tight surface contact with the core strand. The core strand **11** is substantially circular in cross-section while strands **12**, originally of circular cross-section, have been deformed in those regions **13** of their surfaces which correspond to and form the outer surface of the cable. While this deformation may be somewhat exaggerated in the drawings, fairly perceptible corners **14** and **14'** bounding each side of the deformed regions **13** are present. The remaining surface regions **15** of the strands **12** substantially retain their original roundness. That is, the surface region **15** of each strand **12** essentially defines a continuous curve extending from corner **14** to corner **14'** with no intermittent flattened areas.

Due to the cross-sectional configurations of the strands, interstices **16** are formed on the interior of the cable between strands **12** and core strand **11** while superficial valleys **17** are formed on the exterior of the cable between the strands **12**. The interstices **16** are sealed from valleys **17** by the tight contact **18** between adjacent strands **12**. This contact seal is sufficient to effectively prevent coating materials from entering the interstices during an extrusion coating operation which may be subsequently performed on the cable. Thus, as pointed out previously, "imprinting" in the insulating cover of the cable is eliminated.

In addition, it is pointed out that the deformed regions **13** of the cable produce a corresponding decrease in the depth of the valleys **17** and in the effective diameter of the cable. Therefore, less coating material is required to fill the valleys and cover the cable to provide an insulating sheath.

As previously described, the strands **12** are in tight engagement with each other as well as with core strand **11**. These strands are also under substantially equal tension and possess no kinks, all of which directly results from the manner in which the cable is formed to produce the deformed regions **13** on strands **12**. The cable, as a result, may be unrolled from its carrier spool and lie in a substantially straight-line path exhibiting no tendency to spiral.

Formation of the above-described multistrand cable may be accomplished using a conventional stranding machine in combination with an appropriate sizing die, all of which is schematically represented in FIGURE 2 as one embodiment. This apparatus includes a spool **20** from which the core strand **11** is supplied. The core strand is fed axially into the entrance end of the sizing die **25**. Surrounding the core strand as it passes to the die is a concentric array of supply spools **21** containing strands **12**. These supply spools are mounted on a rotatable frame (not shown) of a conventional stranding machine, such as those shown and described in United States Patent No. 1,691,337 and United States Patent No. 2,156,652, among others. While the frame rotates the strands **12** are fed to the sizing die concurrently with the core strand **11** whereupon they become helically wound about the core strand **11**. The helically wound structure is then drawn through the die thereby forcing the strands **12** into tight arrangement around the core strand while their outermost surfaces are deformed to form regions **13** as shown and described with reference to FIGURE 1. A suitable lubricant, such as a mineral oil, may be used during the drawing operation to reduce the drawing force necessary and the resulting multi-strand electrical cable **10** is thereafter withdrawn from the die **25** and wound upon a suitable spool **26** for subsequent treatment such as an extrusion coating process.

The sizing die merely defines a sizing aperture for the strands **12** and core strand **11**. It may be formed by a plurality of rolls arranged so that their axes approximate a circle in much the same manner as some rolling mills. However, it is preferred that the sizing die comprise a block of hard metallic material such as tungsten carbide having the sizing aperture extending therethrough while gradually tapering along its relatively long length.

In deforming the surfaces of strands **12** within the sizing die **25** the strands actually become cold-worked to a limited degree. The amount of cold-working which takes place is limited to cause removal of kinks and equalization of tension among the strands and does not have any significant effect on the physical properties of the strands. The removal of kinks and the equalization of tension among the strands is quite significant in the final multistrand electrical cable in that the cable has no tendency to spiral as is characteristic of conventional stranded cables.

While the multistrand electrical cable is formed by sizing the cable at the point of stranding in FIGURE 2 it should be understood that the stranding operation may take place separately in advance of the sizing operation.

As previously pointed out, multistrand electrical cable having a greater number of individual strands than the cable of FIGURE 1 may also be formed in accordance with the present concepts. Briefly, these larger size multistrand cables may be formed by stranding and sizing successive layers of strands about a central core strand in much the same manner as illustrated in FIGURE 2. As a result, the strands of each layer are deformed in those surface regions forming the outer periphery of the same layer, and are forced into tight arrangement about the inner portion of the cable structure which is surrounded by the layer.

This will be better understood with reference to FIGURE 3 wherein a two-layered multistrand electrical cable is illustrated. Specifically, the cable includes an inner cable structure comprising a core strand **31** surrounded by a single layer of helically wound strands **32**. The strands **32** are in tight engagement with the core strand **31**. This inner cable structure has been sized to produce flattened regions **33** on strand **32** which form the outer periphery of the inner cable structure along with the valleys **34** between the strands. As is apparent, the inner cable structure is identical with the structure of the single-layered cable described with respect to FIGURE 1.

Surrounding the inner cable structure is a second layer of strands **36** which are helically wound in a direction opposite to the strands **32**. The strands **36** are similarly flattened in regions **37** forming the outer periphery of the cable along with the valleys **38** between the strands. Each flattened region **37** is bounded by corners **39** and **39'** while the remaining surface region **40** substantially retains its roundness or continuous curvature. Internal interstices **41**, which periodically cross over the valleys **34** of the inner cable structure, are effectively sealed from the valleys **38** by the tightness of the contact at **42** between adjacent strands **36**. In addition, the strands **36** are in tight contact with the flattened regions **33** of the strands **32**.

Formation of the above-described two layer multistrand

electrical cable, as well as cables of more than two layers, essentially involves duplication of the steps involved in forming a single layer cable. Thus, for example, in FIGURE 4 there is shown the core strand **31** being axially fed from a supply spool **50** to a first sizing die **55**. The strands **32** forming the first layer of the cable are simultaneously fed to the die from spools **51** mounted on a rotating frame (not shown) of a conventional stranding machine. The inner cable structure **45** is thereafter withdrawn from the sizing die **55** and axially fed to a second sizing die **60**. Strands **36** are also fed to the die from spools **52** in the same manner as strands **32** are fed to die **55**, with the exception that the frame is rotating in the opposite direction. The resulting two-layer multistrand electrical cable **46** as described with respect to FIGURE 3 is withdrawn from the die **60** and wound upon a spool **61**.

In this embodiment it should be understood that both layers of strands are cold-worked in their flattened regions to a limited degree by the dies **55** and **60**. The cold-working is limited to removal of kinks in the strands and equalizing the tension among the strands within each layer. This essentially reduces the internal stresses built up within the strands during the stranding operation. The physical properties, such as flexibility and elongation, remain substantially unaffected.

Thus, in accordance with concepts disclosed above, a multistrand electrical cable, having one or more layers of strands, may be conveniently constructed to possess the major advantageous features now possessed individually by conventional cable and compact cable without suffering from the corresponding disadvantageous features.

The following examples will serve to additionally point out certain aspects of the invention.

Example 1

Six individual aluminum strands were stranded about an aluminum core strand and the stranded structure was passed through a sizing die. The diameter of each strand, including the core strand, was approximately 24.3 mils and the minimum diameter of the sizing aperture of the die was about 71 mils.

The resulting multistrand electrical cable had a maximum diameter of about 72 mils. The cable exhibited good properties of flexibility and elongation and had no tendency to spiral when laid out along a path without being anchored.

Example 2

A cable was formed as described in Example 1 and, in addition, an insulating sheath was extruded thereover. There was no evidence of imprinting in the sheath.

Example 3

An AWG No. 1 copper cable was formed in accordance with the following specifications. Six individual copper strands were stranded about a copper core strand. Each of the strands was approximately 111.5 mils in diameter. The stranded structure was then passed through a sizing die having an aperture of 318 mils minimum diameter.

The resulting multistrand electrical cable had a maximum diameter of 319 mils and exhibited good properties of flexibility and elongation. No tendency to spiral was present.

Example 4

A double-layer AWG No. 10 aluminum cable was formed in accordance with the following specifications. Six individual aluminum strands were stranded about an aluminum core strand, each of the strands being approximately 23.5 mils in diameter. The stranded structure was passed through a sizing die having an aperture of about 68 mils minimum diameter. The resulting single-layer cable had a maximum diameter of about 69 mils. Twelve individual aluminum strands, each of about 23.5 mils in diameter, were then stranded about the single layer cable and passed through a second sizing die having an aperture of about 113 mils minimum diameter.

The resulting multi-strand electrical cable had a maximum diameter of about 114 mils and exhibited good properties of flexibility and elongation. The cable had substantially no tendency to spiral when laid out in an unanchored position.

Example 5

A double-layer AWG No. 2 copper cable was formed in accordance with the following specifications. Six copper strands were stranded about a copper core strand and passed through a sizing die having an aperture of about 172 mils minimum diameter. Each of the strands was initially about 60.3 mils in diameter. The resulting single-layer cable, having a maximum diameter of about 173 mils, was stranded with twelve additional copper strands, each of about 60.3 mils in diameter. The stranded structure was passed through a second sizing die having an aperture of 287 mils minimum diameter.

The resulting multistrand electrical cable had a maximum diameter of about 288 mils and was covered with an insulating sheath by extrusion. The cable possessed good properties of flexibility and elongation. No tendency to spiral was exhibited and no imprinting in the insulating sheath was found.

Example 6

A three-layer copper cable of AWG No. 300 was formed in accordance with the following specifications. Six copper strands were stranded about a copper core strand, each of the strands being approximately 91.8 mils in diameter. The stranded structure was then passed through a sizing die having an aperture of 262 mils minimum diameter. The resulting single-layer cable, having a maximum diameter of about 263 mils, was then stranded with twelve additional strands, each being about 91.8 mils in diameter. The stranded structure was drawn through a second sizing die having an aperture of about 437 mils minimum diameter and the resulting double-layer cable had a maximum diameter of about 438 mils. The double-layer cable was then stranded with an additional eighteen strands, each of about 83.3 mils in diameter. The thus stranded structure was drawn through a third sizing die having an aperture of about 611 mils minimum diameter and a three-layer cable of about 614 mils in diameter was produced.

The three-layer multistrand cable was covered with an insulating sheath by the usual extrusion coating process. The sheath showed no signs of imprinting. The cable, in general, exhibited good properties of flexibility and elongation and had no tendency to spiral.

Additional tests were performed on cables having strands of different diameters than those listed above as well as four-layer cables. The results obtained in all instances were in agreement with those obtained in Examples 1–6.

From the above detailed description it will be readily apparent to those skilled in the art that multistrand cables of any numbers of layers of strands may be made in accordance with the concepts of the invention. It is further pointed out that while only copper and aluminum strands have been mentioned in connection with the examples, strands of other metals may be employed, such as bronze, silver, brass, steel, gold, magnesium, nickel, tungsten, zinc and alloys of the same.

Moreover, from Examples 1–6 and the foregoing general description of embodiments of the invention, it will now be understood that a multistrand cable embodying the invention disclosed herein is characterized by a relatively flattened region **13**, **33** or **37** which extends along the length of each layer strand **12**, **32** or **36** and which is positioned in the perimeter of the layer strand **12**, **32**

or **36**, so that it defines that portion of the perimeter which is most remote from a core strand **11** or **31**. It will also be understood that the width of a region **13**, **33** or **37** is limited so that the cross-section of a layer strand **12**, **32** or **36** remains substantially circular. This limiting of the width of a region **13**, **33** or **37** serves to provide substantial wedge-shaped valleys **17**, **34**, and **37** between adjacent layer strands **12**, **32** or **36** and to otherwise provide a cable which does not have the undesirable physical properties which are characteristic of a prior art compact cable. However, even a region **13**, **33** or **37** which is limited in width provides a cable which does not have the undesirable properties of a prior art uncompacted cable.

In connection with the width of a region **13**, **33** or **37**, it will be noted from FIGS. 1 and 3 that the portion of the perimeter of a layer strand **12**, **32** or **36** which is defined by a region **13**, **33** or **37** is approximately twenty-one percent of the perimeter. When the Examples 1–6 are manufactured and examined, it will be found that the portion of the perimeter of a layer strand **12**, **32** or **36** which is defined by a region **13**, **33** or **37** is also approximately twenty-one percent or less.

Thus, from a production standpoint, it will be understood that a multistrand cable embodying the invention is a cable which had a region **13**, **33** or **37** along each layer strand **12**, **32**, or **36** so as to avoid the undesirable characteristics of a conventional uncompacted cable but in which the region **13**, **33** or **37** is limited to a width that defines less than twenty-two percent of the perimeter of a layer strand **12**, **32** or **36** so as to avoid the undesirable characteristics of a conventional compact cable. It will also be understood that many variations and modifications may be made without departing from the spirit and scope thereof and therefore, it is intended that the present invention be limited only as defined in the appended claims.

We claim:

1. In a multistrand cable, a core strand of substantially circular cross-section, and a plurality of layer strands helically wound about said core strand, each of said layer strands being of a substantially circular cross-section and each of said layer strands having a relatively flattened region extending along its length, said relatively flattened region being formed by deforming a layer strand so as to provide in the perimeter of a layer strand a portion of said perimeter which is most remote from said core strand and which is less than twenty-two percent of said perimeter.

2. The cable of claim **1** in which the core strand and layer strands are formed from a metal selected from the group consisting of aluminum, copper, silver, brass, bronze, gold, magnesium, nickel, tungsten, steel, zinc, and alloys of the same.

3. The cable of claim **1** in which there are at least two layers of helically wound layer strands surounding the core strand with each successive layer being helically wound in a direction opposite to the preceding layer.

4. The cable of claim **1** in which each of the layer strands is in sealing engagement with the adjacent layer strands to effectively seal off the internal interstices of the cable.

5. The cable of claim **1** in which an insulating sheath surrounds said layer strands.

6. The cable of claim **1** in which said plurality of layer strands are a first plurality of layer strands and including a second plurality of layer strands helically wound about said first plurality of layer strands.

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