Sept. 8, 1970 H. T. PAYNE 3,527,487

MECHANICAL SPLICE

Filed Nov. 24, 1967

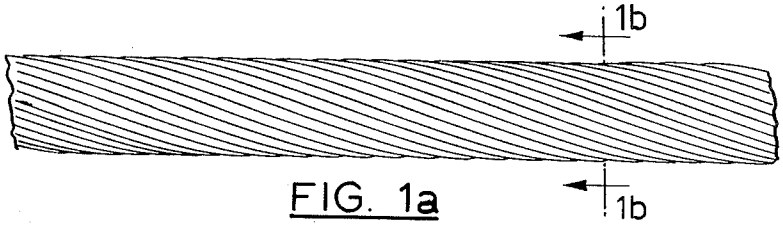


FIG. 1a

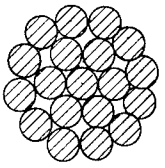


FIG 1b

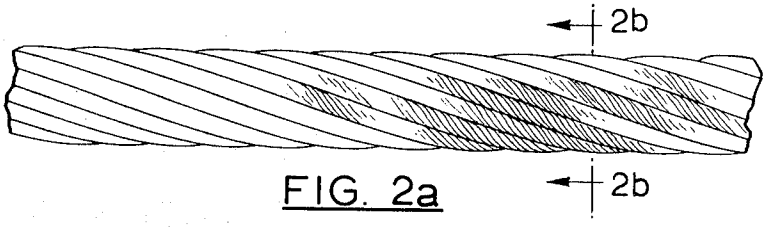


FIG. 2a

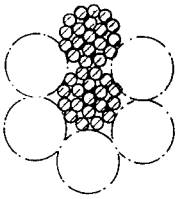


FIG. 2b

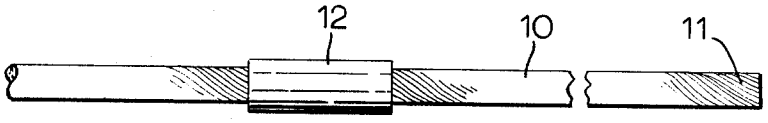


FIG. 3

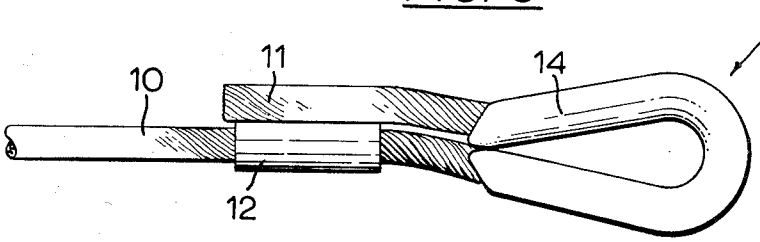


FIG. 4

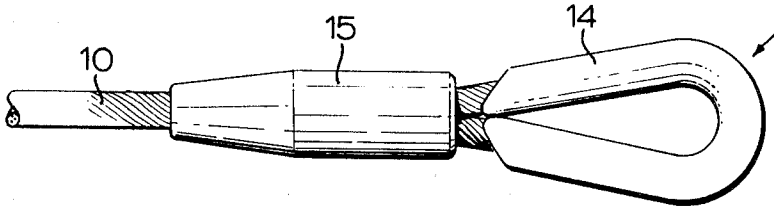


FIG. 5

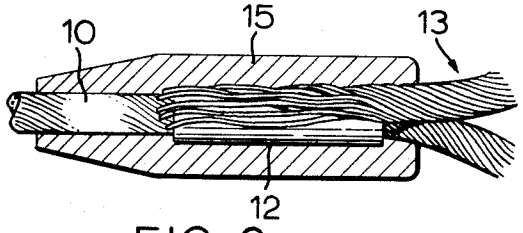


FIG. 6

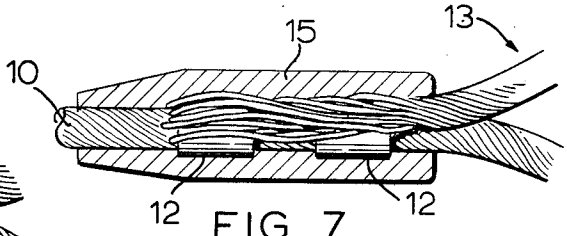


FIG. 7

INVENTOR.
HARVEY T. PAYNE

BY Douglas S. Johnson

Attorney

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MECHANICAL SPLICE

Harvey Thomas Payne, Midland, Ontario, Canada, assignor to Greening Donald Ltd.

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ABSTRACT OF THE DISCLOSURE

A mechanical splice for forming a turn-back loop-end in wire strand—as opposed to wire rope—including at least one thin-walled sleeve placed over the live end of the loop, and a compressible ferrule swaged over the sleeve, live end and dead end of the loop.

FIELD OF THE INVENTION

This invention relates to wire strand and provides an apparatus and method for making a mechanical splice therein. The invention is particularly directed to an apparatus and method for forming a loop-end in wire strand.

When a turn-back loop-end is formed in wire strand, and a mechanical splice is made in the strand, the full or catalogue strength of the strand has been most difficult to attain. Thus, and since the strand is intended for use in tension, the maximum tensile efficiency of the strand with a loop-end formed therein becomes less than that of the strand per se. Therefore, it has been necessary for designers when designing structures using wire strand having loop-ends formed therein to assume that as little as 80% of the maximum tensile efficiency according to catalogue figures of the strand strength can be attained, and accordingly it has been necessary to prepare the design calling for larger and heavier wire strand than would otherwise be required so as to make up for the deficiency in tensile strength that occurs at the loop-end. Because heavier strand is used than might otherwise be required, the structure is, in a sense, overdesigned; and the cost of such an overdesigned structure is higher than it would be if lighter strand could have been used.

By wire strand as discussed in this application, there is meant a strand which is formed in one or more stranding operations, and which is formed of a plurality of wires of steel, coated or uncoated. The distinction is made between wire strand and wire rope, in that wire rope is formed by laying or closing a plurality of strands about a core.

Wire strand is manufactured having a variety of diameters, varying from several fractions of an inch to about two inches; and may be variously known as guy strand, tower strand or bridge strand, depending on the purpose for which it is intended and used. For example, guy strand may have a diameter of less than one-quarter of an inch and be used for guying such structures as a television mast on the roof of a home; tower strand may have a diameter ranging from one-quarter of an inch to one inch and may be used to guy or support transmitting towers which may be up to one thousand feet or more in height; and bridge strand may have a diameter of up to two inches or better and is used to support the towers of suspension bridges and for other uses in bridge and heavy construction generally. Obviously, the individual wires from which a wire strand is formed may have diameters ranging from one-tenth of an inch or less up to better than one-quarter of an inch; and a wire strand may comprise anything from six or seven up to several hundred wires.

Wire strand is sometimes used instead of wire rope where cost is a consideration in the design of the installation, and where there will be little flexing or working of

the strand. Also, wire strand is subject to less elongation as load is applied than wire rope; and it is particularly adapted for static installations such as those discussed above. However, one difficulty that arises in the use of wire strand as opposed to the use of wire rope, is that it is more difficult to achieve tensile efficiency in wire strand where a mechanical splice is to be formed therein at a loop-end. The reason for this is that the surface of wire strand is smoother than that of wire rope (and is subject to greater deformation than wire rope when lateral compression is applied) as will be discussed in greater detail hereafter.

Tensile efficiency of a wire strand when in tension is a measure of the tensile strength of the wire strand which can be developed as compared with the catalogue tensile strength of the strand, and is calculated in accordance with the following equation:

$$\text{Tensile efficiency} = \frac{\text{Actual tensile strength developed}}{\text{Catalogue strength}} \times 100$$

The catalogue strength of a wire strand (or for that matter, a wire rope) is a standard which has been adapted by the wire strand and rope industry and which is used and referred to by designers as the full strength of the wire strand. In actual fact, of course, the ultimate strength of the wire strand is above the catalogue strength, usually by about 5%, thereby providing a margin of safety over and above any such margin of safety which a designer may use. For example, the catalogue strength of a five-eighths inch diameter 1 x 19 bridge strand is 48,000 pounds, whereas the ultimate strength of the strand is in the order of 51,000 pounds. By a reduction in maximum tensile efficiency, therefore, it is meant that the full tensile strength of a wire strand according to its catalogue strength cannot be developed.

In general, in order to develop maximum tensile efficiency of wire strand having a turn-back loop-end secured with a compression fitting, it is necessary to restrict slippage of the strand under the fittings and to eliminate distortion to the main body (or live end) of the strand. It is particularly important that distortion of the live end of the strand be substantially eliminated, as is discussed in greater detail hereafter.

DESCRIPTION OF PRIOR ART

In the past, when it has been desired to form a loop-end in wire strand, a plurality of wire rope clips have been used to secure the live end and dead end of the strand together so as to form the loop. However, as the tensile load was applied to the strand, it was necessary to re-tighten the wire rope clips to overcome slippage and to accommodate distortion. 100% tensile efficiency cannot be obtained under such conditions. Alternatively, attempts have been made in the past to use aluminum or stainless steel compression ferrules of the type used with wire ropes. However, such ferrules cause considerable distortion of the live end of the strand, and 100% tensile efficiency cannot be attained. Also, there has been some problem of slippage of the strand due to its smooth surface unless long compression sleeves were used.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a mechanical compression splice for wire strand, which is particularly adapted for forming turn-back loop-ends in the wire strand, and by which substantially the full maximum tensile efficiency of the wire strand can be developed.

It is a further object of this invention to provide a method for forming a turn-back loop-end in wire strand,

whereby substantially the full maximum tensile efficiency of the wire strand can be developed after the strand is subjected to a tensile load.

BRIEF DESCRIPTION OF THE DRAWING

These and other objects and features of the invention are discussed below in association with the drawings, in which:

FIGS. 1(*a*) and 1(*b*) are a typical side view and cross-section respectively (to a different scale) of a length of wire strand;

FIGS. 2(*a*) and 2(*b*) are a typical side view and cross-section respectively (to a different scale) of a length of wire rope;

FIG. 3 shows a length of wire strand during the first step of forming the turn-back loop-end therein according to this invention;

FIG. 4 shows a length of wire strand having a turn-back loop formed therein;

FIG. 5 illustrates a complete mechanical splice forming a loop-end in a wire strand, but before the splice is compressed so as to be effective;

FIG. 6 is a cross-sectional view of the mechanical splice of FIG. 5 taken in the plane of the loop but not taken through the wire strand itself after the splice has been compressed; and

FIG. 7 is a figure similar to FIG. 6 but showing a mechanical splice in which two sleeves have been used in accordance with this invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIGS. 1(*a*) and 1(*b*), compared with FIGS. 2(*a*) and 2(*b*), illustrate that the outer surface of a wire strand is a smoother surface than that of a wire rope of the same nominal diameter. There are considerably fewer crevices or interstices between the wires forming the outside surface of the strand than there are between the wires forming the strand and between the strands themselves of the wire rope. Also, the crevices between the strands of the wire rope are much deeper than any crevice between the wires of the wire strand of the same size. Reference will be made to these figures in the discussion of compression sleeves and ferrules which is made hereafter.

In general, the invention comprises a compression splice which is particularly adapted for use in forming loop-ends in wire strand. The compression splice comprises at least one thin walled sleeve which is closely fitted or pressed to the wire strand at a place on it such that it will be on the live end of the loop after it is formed. After the sleeve is fitted to the strand, and the loop is formed, a compressible ferrule is placed over the sleeve and loop-ends and is pressed to the sleeve and loop-ends so as to form the splice and the loop. An abrasive grit may be applied to the strand beneath the sleeve, and may further be applied to the loop-ends and sleeve beneath the compression ferrule.

Turning to FIG. 3, a length of wire strand 10 including the butt end **11** thereof is shown, and a sleeve **12** is shown around the wire strand **10**. The positioning of sleeve **12** on the wire strand **10** is chosen so that when the loop is formed as shown in FIG. 4, the sleeve **12** is in the area where the mechanical splice forming the loop will be made, and so that the sleeve **12** is on the live end of the loop-ends.

By "live" end of the loop-ends, as can be seen from FIG. 4, it is meant that the live end is that one of the two loop-ends in which the full tensile load applied to the wire strand will be transmitted to the loop. The other loop-end, which includes the butt end of the wire strand, is known as the "dead" end of the loop.

FIG. 4 shows a loop **13** formed in the wire strand **10** so that butt end **11** lies further from the loop **13** than sleeve **12**. In forming the loop, and depending upon the purpose to which the loop will be put, it is often advisable to use a thimble **14**, such as that illustrated by way of example only, in FIG. 4. The use of thimble **14** forms no part of this invention.

The sleeve **12**, of which at least one must be used according to this invention, is a thin-walled sleeve, preferably of steel. The inside diameter of sleeve **12** is chosen so that when it is applied to the wire strand **10** as illustrated in FIG. 3, the sleeve fits very snugly to the wire strand. That is, when sleeve **12** is fitted to wire strand **10**, there is no opportunity for the sleeve **12** to move freely back and forth on the wire strand, nor is there an opportunity for the wire strand **10** to slap or move laterally within sleeve **12**. Of course, in order that sleeve **12** is snugly fitted to the wire strand **10**, the sleeve may be pressed using suitable compression dies and presses to the wire strand. It is not, however, necessary to press the sleeve to the wire strand if a snug fitting between the two can be otherwise achieved. It is important that the snug fitting between the sleeve and wire strand be achieved so as to prevent or minimize distortion of the wire strand during the compression fitting of a compressible ferrule to form the mechanical splice, as will appear hereinafter. Also, whether one or more sleeves are used is dependent, to a degree, upon the wire strand being used; but for wire strands of greater diameter than one-half inch, it is usual to use two sleeves.

Once the loop **13** has been formed in the wire strand **10** in the manner shown in FIG. 4 (and the thimble **14** fitted within the loop, if it is to be used) a compressible ferrule **15** is placed over the live and dead ends of the loop and over the sleeve **12**. The compressible ferrule **15** is one of the type commonly used in association with wire rope, and may be of aluminum or other metal which is malleable. Usually, the compressible ferrule is of an aluminum alloy which is very malleable and is highly resistant to corrosion of the type known to the trade as "Talurit." The size of the compressible ferrule **15** is chosen so that it fits closely to the loop-ends when it is first placed thereat. In general, the crosswise inner dimension of the compressible ferrule **15** is approximately equal to twice the wire strand diameter so as to accommodate the live and dead ends of the loop lying side by side; and the inner height of the compressible ferrule is approximately the diameter of the wire strand. Of course, sufficient dimensional clearance within the compressible ferrule must be made so as to accommodate the thin walled sleeve **12** fitted over the live end of the loop.

When a compressible ferrule is compressed about the wire rope or wire strand fitted into it so as to accomplish the mechanical splice being made, the material of the ferrule being malleable tends to flow under high pressures. The compression of the compressible ferrule is accomplished by the use of suitable dies and presses capable of reaching the high pressures required. The dies are of very hard steel, and are so shaped as to fit to the compressible ferrule and, under pressure, to shape the ferrule. Usually the dies are also constructed so as to accommodate the removal of the flash which occurs during the compression operation on the ferrule as the material of the ferrule tends to flow. The compression operation is referred to as swaging.

Referring now to FIGS. 1(*a*), 1(*b*), 2(*a*) and 2(*b*), it can be seen from a study particularly of FIG. 2(*b*) that as a compressible ferrule is swaged to wire rope, there are a number of crevices between the wires forming the strands of the rope and between the strands. In particular, the crevices of interstices between the strands are quite deep, and as the material of the compressible ferrule is swaged to the wire rope, it flows into the crevices and around the rope. The wire strand of FIG. 1(*b*) on the other hand has a much smoother surface than that of the wire rope, with considerably fewer crevices or interstices, and with no crevice as deep as that formed in the surface of the wire rope. Thus, the total surface area

of the wire strand which can contact the material of the compressible ferrule after it is swaged, is much less than the total surface area of the wire rope having the same nominal diameter. Since there is less contacting surface area between the wire strand and the compressible ferrule than there would be between wire rope and the compressible ferrule, the likelihood of slippage is considerably greater with the wire strand, and the frictional forces set up between the strand and the ferrule material are much less. It appears, then, that because there is apparently less gripping between the ferrule material and the wire strand, the use of compressible ferrules alone when forming loop-ends in wire strand has thereby resulted in somewhat inefficient splices and reduced maximum tensile efficiency of the strand.

Reference to FIGS. 6 or 7 shows the manner in which the material of the compressible ferrule has flowed around sleeve **12** Because there has been considerably more flow of the material of the compressible ferrule **15** during the swaging operation around the sleeve **12** than there would have been had not the sleeve been present, the gripping developed between the wire strand with the sleeve and the compressible ferrule is greater. Also, some distortion has occurred in the dead end of the loop, creating a greater surface area and deeper crevices into which the material of the ferrule might flow. The likelihood of slipping between the ends of the loop or between the wire strand and the swaged ferrule are therefore much less, and an efficient splice is accomplished.

It is noted, however, that little or no distortion of the live end of the loop has been permitted due to the presence of the sleeve. There is very little distortion of the live end of the loop beneath the sleeve **12** because the sleeve's dimension and material require a higher unit pressure to swage the sleeve than to compress or swage the ferrule during the swaging operation. Thus, there is little or no swaging of the sleeve even though the ferrule has been successfully swaged and the material thereof flown in and around the crevices on the surface of the wire strand.

It is most important that there be as little distortion of the live end of the loop as possible, and preferably no distortion, because distortion of the wire strand results in uneven loading of the various wires making up the strand as tension is applied. With uneven loading of the constituent wires of the live end of the loop, and the concomitant uneven loading thereon, inefficient use of the strand during tension results. Because the ultimate strength of the wire strand is usually 5% or better higher than the catalogue strength, some distortion up to a maximum of about 5% of the main strand may be permitted and still 100% tensile efficiency of the wire strand can be attained.

The use of two or more sleeves as illustrated in FIG. 7 greatly enhances the likelihood that there will be no or very little distortion of the main strand as the compression ferrule is swaged. Particularly with larger sizes of strand (say above one-half inch diameter), the size and length of the compression ferrule becomes such that the use of the second or subsequent sleeve **12** is advisable. In general, two sleeves have been found to be sufficient. The distortion which occurs on the dead end of the loop is of little consequence and, in fact, appears advantageous in view of the fact that greater penetration of the material of the compressible ferrule as it flows during swaging is possible. The tensile load applied to the wire strand and transmitted through it to the loop is through the live end of the loop, and studies have shown that the portion of the load retransmitted by the dead end of the loop is considerably less than half of the tensile load. (See Lierow: The Mechanical Principles of the Talurit Wire Rope Clamp . . . DRAHT EX. 23/June 1954, at pages 23 and 24.)

The use of an abrasive grit beneath the sleeve **12** and/or coating the live and dead ends of the loop and the sleeve beneath the compressible ferrule, can result in better frictional characteristics between the live end and the sleeve and between the live and dead ends, the sleeve and the compressible ferrule. Because the frictional retention of the live end in the sleeve or of the live and dead ends within the compressible ferrule is greater when the abrasive grit is used, the maximum tensile efficiency possible can be even greater than without the use of the grit. However, it is to be pointed out that the use of grit is optional to the main purpose of this invention, which is to provide a mechanical splice for forming a loop-end in wire strand using at least one sleeve **12** over the live end of the loop and the compressible ferrule **15**. Suitable abrasive grits that may be used are aluminum oxide and silicon.

In any event, the use of the sleeve **12** over the live end of the loop beneath the compressible ferrule greatly increases the resistance to slippage of each of the live and dead ends beneath the ferrule when it is swaged. Further, even if a very long ferrule were used, and since resistance to slippage is a function of the length of contact between the material of the ferrule and the dead end of the strand, it would still be necessary to use the sleeve on the live end of the strand so as to preclude distortion of the live end or keep distortion within allowable limits. When two sleeves are used, it has been found that the dead end of the loop bridged over the sleeves concaved between them as the ferrule was compressed, thereby further increasing its resistance to slippage.

There follows several examples and test results made on various sizes of wire strand and as will appear, and which indicate the increase in the tensile efficiency of wire strand having a loop-end formed therein and utilizing the mechanical splice of this invention to construct the loop-end.

All of the actual test results indicated below are on wire strand made by the assignee company of this application, and in each of the mechanical splices constructed according to this invention, two sleeves **12** were used with abrasive grit coated underneath them and over the live and dead ends of the loop.

Example 1

A 13/16 inch nominal diameter strand was taken, and zinc cones were cast on each end of the strand which was then placed in a tensile machine and load applied thereon until the strand ruptured. This test, using zinc cones at either end of the strand, is recognized as the test for determining the true ultimate strength of the strand. An identical piece of 13/16 inch nominal diameter strand was taken, and a zinc cone was cast on one end and a turn-back loop-end formed on the other end in accordance with this invention. The results of these two tests were as follows:

TABLE 1.—TEST RESULTS OF EXAMPLE 1

Strand tested:	Rupture strength in pounds
13/16 inch strand, zinc cone on both ends	95,730
13/16 inch strand, zinc cone at one end, turn-back loop at the other end	94,370

The loss in efficiency, or in other words, the reduction of the rupture strength of the strand of the sample having the turn-back loop formed at one end was 1,360 pounds, or approximately 1.5%. The catalogue strength of 13/16 inch diameter strand, as explained above, is 80,000 pounds.

Example 2

Four samples of nominal 5/8 inch bridge strand were taken, and zinc cones were cast on one end of each of the samples. On two of the samples, a loop-end was formed and was completed using a long, compressible, aluminum ferrule, but without the use of any sleeve as taught by this invention. The other two samples had loop-ends formed in them in accordance with this invention and as discussed above. All of the samples had abrasive grit coated on the loop-ends beneath the compressible ferrule.

The results of the tests made on the four samples are as follows:

TABLE 2.—TEST RESULTS OF EXAMPLE 2

Sample tested:	Rupture strength in pounds
(1) Long ferrule, no sleeve	45,130
(2) Long ferrule, no sleeve	44,350
(3) Long ferrule, 2 sleeves	49,400
(4) Long ferrule, 2 sleeves	49,820

The increase in rupture strength of samples 3 and 4 having loop-ends formed therein in accordance with this invention was in the order of 10% over the first two samples tested. Further, since the catalogue strength of 5/8 inch bridge strand used is 48,000 pounds, each of the two samples tested having loop-ends formed in accordance with this invention exhibited tensile efficiency of greater than 100%.

Example 3

Samples of various diameters of strand as manufactured by the assignee company of this application were tested in the manner as described above with respect to samples 3 and 4 of Example 2. That is, each of the samples of the various diameters of strand had a zinc cone cast at one end and a loop-end formed at the other end in accordance with this invention. The result of the test made on each of the various samples was compared with the published catalogue strength for that sample, and the percentage tensile efficiency for each sample was calculated. The results of these tests were as follows:

TABLE 3.—TEST RESULTS OF EXAMPLE 3

Diameter of strand sample	Catalogue strength in pounds	Actual strength in pounds	Percent tensile efficiency
9/16"	38,000	41,570	109
3/4"	68,000	74,460	110
13/16"	80,000	94,370	117
7/8"	92,000	106,000	114
15/16"	108,000	112,000	104
1 1/16"	138,000	138,770	101
1 1/8"	156,000	160,530	103

In each sample tested in Example 3, and indeed in each of the samples tested in Examples 1 and 2 which had loop-ends formed in accordance with this invention, the tensile efficiency of the strand having the loop-end formed therein in accordance with this invention was greater than 100%.

A compression splice for forming a loop-end in wire strand has been disclosed wherein at least one thin-walled sleeve is placed over the live end of the loop and a compressible ferrule of greater length than the sleeve is swaged over the live and dead ends of the loop and at least one sleeve. A method of forming the loop-end in the wire strand is also disclosed. The present invention further prescribes that although the use of at least one sleeve placed over the live end of the formed loop is necessary, the use of abrasive grit either beneath the at least one sleeve or coating the sleeve and the live and dead ends beneath the compressible ferrule is optional. The material of the thin-walled sleeve is usually steel, but any metal having greater compressive strength—that is, requiring a higher unit pressure for swaging—than the metal of the compressible ferrule, may be used.

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

1. A compression splice for forming a turn-back loop-end in wire strand, comprising: a wire strand composed of a plurality of uniformly twisted wires, at least the major number of wires at the surface each having substantially the same diameter; at least one thin-walled sleeve placed snugly over the live end of said loop-end in the area where said loop-end is to be formed; said dead end being positioned in substantially undistorted condition side-by-side against said at least one sleeve; and a compressible ferrule of greater length than said at least one sleeve placed over said sleeve and the live and dead ends of the loop-end, said compressible ferrule being swaged in place to complete said loop-end in said wire strand, whereby said wires of said dend end are slightly spread apart and the material of said ferrule extends into the spaces between said wires; the resistance to deformation of said at least one sleeve being at least as high as that of said compressible ferrule.

2. The compression splice of claim 1 wherein a coating of abrasive grit is placed on the wire strand of the live-end of said loop beneath said at least one sleeve.

3. The compression splice of claim 1 wherein said at least one sleeve is pressed to the wire strand of said live end of said loop without substantial distortion to said wire strand.

4. The compression splice of claim 1 wherein two spaced, thin-walled sleeves are snugly fitted to the live end of said loop, and said sleeves are of steel.

5. A compression splice for forming a turn-back loop-end in wire strand, comprising: at least one thin-walled sleeve placed snugly over the live end of said loop-end in the area where said loop-end is to be formed; and a compressible ferrule of greater length than said at least one sleeve placed over said sleeve and the live and dead ends of the loop-end, said compressible ferrule being swaged in place to complete said loop-end in said wire strand; the resistance to deformation of said at least one sleeve being at least as high as that of said compressible ferrule;

and wherein a coating of abrasive grit is placed on the wire strand at the live end of said loop on at least one of beneath said at least one sleeve and over said at least one sleeve, and also over the live and dead ends of said loop beneath said compressible ferrule.

6. The compression splice of claim 5 wherein said abrasive grit is chosen from the group consisting of aluminum oxide and silicon grit, and said compressible ferrule is made of metal chosen from the group consisting of aluminum, malleable aluminum alloys and stainless steel.

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