Feb. 14, 1961 D. HIMMELFARB ET AL 2,971,321

PLIED CORD ROPE CONSTRUCTION

Filed Oct. 16, 1956

Fig. 1.

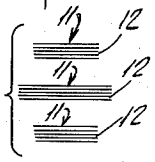


Fig. 2.

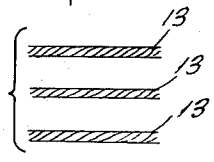


Fig. 3.

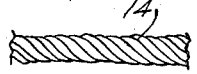


Fig. 4.

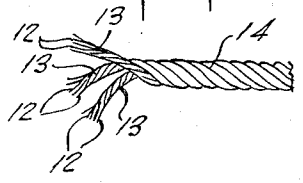


Fig. 5.

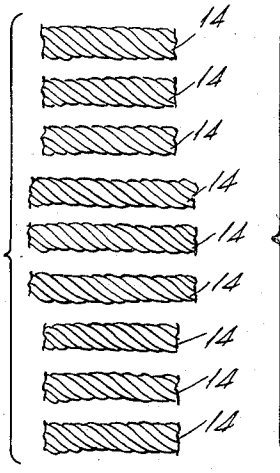


Fig. 6.

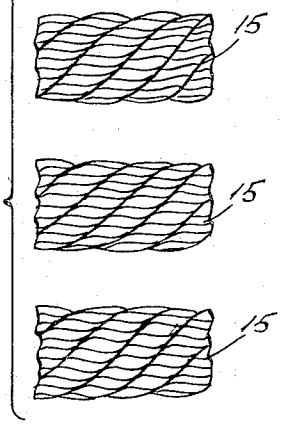
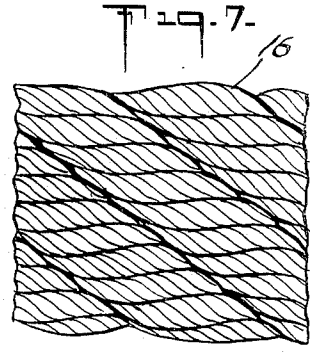


Fig. 7.



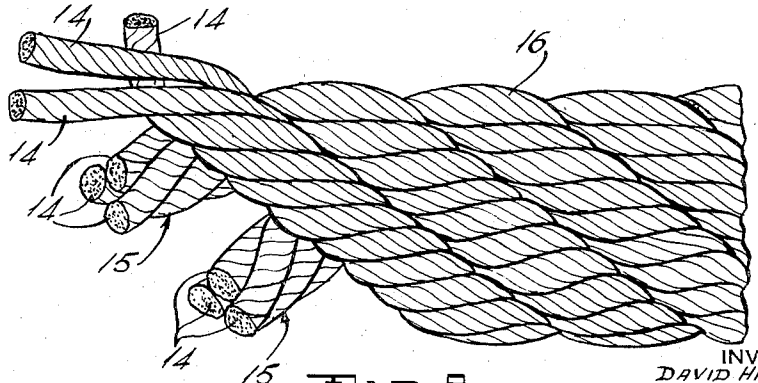


Fig. 8.

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PLIED CORD ROPE CONSTRUCTION

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12 Claims. (Cl. 57—139)

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The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

This invention relates to ropes and methods of making ropes. In particular the invention relates to stranded ropes of man-made or natural fibers and to methods of making such ropes. For example, it relates to the structure and fabrication of ropes made from man-made fibers of which nylon, Dacron, Orlon, polyethylene, etc. are examples, and natural fibers, of which manila, sisal, etc. are examples, by twisting the fibers into yarns, sometimes called threads; twisting two or three of the yarns together into a cord; twisting a number of cords together into strands, and the strands into rope.

An object of the invention is to provide a rope and method of making same.

Another object is to provide a stranded rope of man-made or natural fibers in which the strands are made from a balanced cord structure and further to provide a method of making same.

Another object is to provide a stranded rope of man-made or natural fibers in which there is imparted to the strands a twist reservoir for the acquisition of additional twist associated with the stresses and strains of service whereby the effects of such stresses and strains can be absorbed without deformation of the strands and development of kinks, bulges and cockles.

Other objects and many of the attendant advantages of this invention will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawing wherein;

Fig. 1 is a diagrammatic view showing a plurality of filaments of man-made or natural fiber.

Fig. 2 is a diagrammatic view showing the filaments twisted into a plurality of yarns.

Fig. 3 is a diagrammatic view showing the yarns twisted into a cord.

Fig. 4 is a perspective view of the yarn in Fig. 3 that is partly untwisted at the left end for clarity of illustration.

Fig. 5 is a diagrammatic view showing a plurality of cords.

Fig. 6 is a diagrammatic view showing the cords twisted into a strand.

Fig. 7 is a diagrammatic view showing the strands twisted into a rope, and

Fig. 8 is a perspective view of the rope in Fig. 7 that is partly untwisted at the left and for clarity of illustration.

Conventional rope structures are formed by a successive reversal of direction of twist of components related to the twisted structure. When the filaments or fibers are twisted into yarns in manner such that the spiral of the twist is upward to the right (also termed right twist or Z twist), the strands are formed by twisting a number of such yarns together in the reverse direction

so that the spiral of the twist is upward to the left (also termed left twist or S twist). The rope is completed by twisting three or more strands in reverse direction so the spiral of the twist is upward to the right. By this process of reversal of twist, the filaments or fibers become compacted into a structurally balanced form, designated the rope, required for the service intended.

When such conventional rope is placed in service, the structural balance is upset by conditions of service. Tension tends to untwist the rope by tending to untwist the group of strands. But because of the reversal of twist between rope and strands, each individual strand becomes twisted more tightly and thereby harder. With increase in tension this effect continues until there results an internal rearrangement in the structure of the strand, with the resulting deformation manifesting itself by the appearance of kinks and bulges, also termed cockes. These deformations result in a loss of strength and reduce the serviceability of the rope. Wetting will swell the rope to increase the girth and this will have the effect of hardening and tightening the rope to thereby increase the degree of twist and make the strand even more liable to kinks and bulges when tension is applied in service or when rope is handled during service operations.

Conventional ropes of man-made fiber such as nylon, Dacron and Orlon, when exposed to the weather and sunlight, will shrink and tighten the rope structure to further reduce serviceability. Attempts at overcoming these adverse effects by reducing the relative amount of twist in the strands and ropes has developed other defects in serviceability. The lesser twist yields a rope and strand structure that is not as compacted and which on handling or bending will demonstrate inferiority, and will be subject to more extensive damage than the rope of the tighter twist.

While the behavior described relates to all conventional fiber rope structures, it is particularly pertinent to ropes of man-made fiber such as nylon, Dacron and Orlon since by the nature of the fibers such ropes must be compacted with greater twist than ropes of natural fiber such as manila or sisal. In the process of ropemaking it has been established that where degrees of twist employed are comparable, such ropes of man-made fiber are not sufficiently compact in structure for proper serviceability. The additional twist to provide the additional compacting and hardness is necessarily of such magnitude as to afford little opportunity to absorb the shifting stresses in service so that deformation of strands is accelerated. In the process known as heat setting, the strands or yarns of the man-made fibers are stabilized by exposure to hot water, steam, or dry heat, so that the resulting shrinkage serves to provide additional compacting and hardness. However, the shrinkage in this case is of magnitude such as to result in deformation of the strands with consequent kinks and bulges.

The present invention overcomes these defects to produce a rope which will, in general, possess the attributes of a rope properly compacted and hardened by twist for greater serviceability, but which will remain serviceable and resist the strand deformation and its associated kinks and bulges when subject to service stresses and strains. Our invention marks a sharp departure from conventional ropes by providing a balanced cord structure for twisting into strands in place of the unbalanced twisted yarn structure conventionally employed for twisting into strands. The term cord we define as a flexible, continuous braided or twisted structure formed from yarn and adapted to be twisted into strand, generally less than 3/16 inch diameter and having the yarn twist structurally balanced against the cord twist to maintain compactness. The balance is evidenced by

the restraint of freely twisting back on itself when the two parallel sides of an extended loop of the cord are in proximity to one another. By this balanced cord construction, a desired compacting can be attained with considerably less twist in the strand, so that there is imparted to the strand a twist reservoir for the acquisition of additional twist associated with the stresses and strains of service, whereby the effects of such can be absorbed without deformation of the strands and development of kinks, bulges and cockles. The compacting effect may be regulated by the extent of twist in the cord in relation to the strand.

In practicing the invention to make a rope of nylon, for example, the nylon filaments **11** shown in Fig. 1 are bunched into ribbons **12** which are twisted into yarns **13**. For convenience of illustration yarns **13** are shown as having **S** twist. The amount of twist will be determined by the diameter of the yarn and may be varied to increase or lessen the compacting effect of the twist. We have found the following relationship to exist:

$$\text{Tan } \theta = \text{turns per inch} \times \text{diameter of yarn} \times \pi$$

where θ is the helical angle of twist. The value of θ will ordinarily be in the range of 15° to 25°.

Two or more yarns **13** are next twisted into cord **14** by a laying operation in **Z** direction reverse to the direction of **S** twist of the yarns **13**. By this process, the yarn **S** twist is maintained relative to the cord **Z** twist, so that the cord **14** is structurally balanced as previously described. The state of balance we have found to exist when the **Z** twist in the cord **14** is within the range of 70 to 85 percent of the **S** twist in the yarn **13**. While nylon has been indicated in the foregoing illustration, the structure of the cord **14** and the twist relationship is equally applicable to man-made fibers such as Orlon, Dacron, polyethylene, and natural fibers such as manila and sisal.

The formation of the strands **15** from the cords **14** is illustrated in Figs. 5 and 6. In forming the strands **15**, a number of cords **14** are twisted together in the usual **S** twist reverse to the **Z** twist of the cord **14**. A forming tube (not shown) usual to the art is employed. It has been our experience that the relationship between the number of cords **14** and the dimension of the bore of the tube is critical to appearance and performance of the rope. Such relationship will vary according to the degree of compactness of the cord **14**, its size, the smoothness of its surface, and the nature of the fiber. For one type of nylon cord **14** laid with an angle of twist of 20° and consisting of three yarns **13**, each 15,120 denier in size, the relationship has been established according to the following:

$$D = 0.006825N + 0.4142$$

where D is the bore dimension in inches (range 0.60 to 1.2 inches) and N the number of such cords **14**. Similar relationships have been determined for other cords of natural and man-made fibers in other sizes to reflect the variable factors cited. The distribution of the cords **14** with respect to arrangement within a strand **15** we have found also to be critical to appearance and performance of the rope. The layer of cords **14** comprising the surface of the strands **15** we have found also dependent upon the degree of compactness of the cord **14**, its size, the smoothness of its surface, and the nature of the fiber. The average relationship for most cords **14**, with adjustment to reflect the variable factors cited, we have found to be:

$$\text{Number of surface yarns} = \frac{4.2(D-d)}{d}$$

where D is the tube bore dimension in inches, and d is the diameter in inches of the cord **14**. The turns imparted to the strand **15** will be determined by the ultimate compactness and hardness of the rope **16**, which is to be attained by twisting three or more strands **15** together, and cannot be defined by specific formulation, but rather must be incorporated according to the judgment and art of the ropemaker. It has been our experience that for a given compactness and hardness of rope structure, the strand man-made fibers such as nylon, Dacron and Orlon will require a greater degree of twist than the natural fibers such as manila and sisal. One type of nylon, for example, will require a strand turn or length of spiral pitch 75–85 percent of twist required for manila of comparable size. The term filament is intended to include not only continuous filaments but also filaments made of staple fibers.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

We claim:

1. The method of forming a stranded rope structure which comprises successively twisting in one direction a plurality of fibers or filaments into yarn, twisting in the opposite direction a plurality of yarns, preferably three, into a cord which is in balance in relation to the torsional forces manifest between the yarns and the cord, twisting in said one direction a plurality of cords into a strand, and twisting in said opposite direction a plurality of strands into a rope.

2. The method of forming a stranded rope structure which comprises successively twisting in one direction a plurality of thermoplastic filaments into yarn, twisting in the opposite direction a plurality of yarns into a cord which is in balance in relation to the torsional forces manifest between the yarns and the cord, twisting in said one direction a plurality of cords into a strand, and twisting in said opposite direction a plurality of strands into a rope.

3. The method of forming a stranded rope structure, which comprises successively twisting in one direction a plurality of fibers or filaments into yarn with a helical angle of twist of about 15° to 25°, twisting a plurality of such yarns in a reverse direction into a cord in degree to balance the opposing torsional forces manifest between the yarns and the cord, twisting a plurality of such cords into a strand in direction reverse to the twist of each cord, and twisting a plurality of such strands in direction reverse to that in each strand into a rope but with a moderate amount of twist to attain flexibility.

4. The method of forming a stranded rope which comprises successively twisting a plurality of fibers or filaments into yarns with a helical angle of twist of about 15° to 25°, twisting a plurality of such yarns, preferably three, together in reverse direction into a cord, the degree of twist measured by the turns per foot amounting to 70 to 85 percent of the turns per foot of the component yarns, thereby effecting balance between the opposing torsional forces manifest between the cord and the component yarns, twisting a plurality of such cords into a strand in direction reverse to the twist of each cord, and twisting a plurality of such strands in reverse direction to each strand, into a rope with moderate twist to attain flexibility.

5. A rope comprising a plurality of strands twisted together, each strand being formed of a plurality of cords twisted together, each cord being formed of a plurality of yarns twisted together, and each yarn being formed of a plurality of filaments twisted together, the direction of twist varying alternately from filaments to yarn, yarn to cord, cord to strand, and strand to rope, and the twist in the yarns and cords being balanced with respect to the torsional forces manifest between the yarns and the cords.

6. The rope as set forth in claim 5, wherein the helical angle of twist of the filaments into yarn is about 15° to 25°.

7. The method of making a stranded rope which com-

prises twisting a plurality of filaments into yarns, twisting a plurality of such yarns into cords, and twisting a plurality of such cords into strands, twisting at least three of such strands into a rope, varying the direction of twist alternately from filament to yarn, yarn to cord, cord to strand, and strand to rope, and balancing the twist in the yarns and cords to provide a balanced cord.

8. A rope comprising a plurality of strands twisted together, each strand being formed of a plurality of cords twisted together, each cord being formed of a plurality of yarns twisted together, and each yarn being formed of a plurality of filaments twisted together, the direction of twist varying alternately from filaments to yarn, yarn to cord, cord to strand, and strand to rope, and the twist in the cord being within about 70 to 85 percent of the twist in the yarns.

9. The rope as set forth in claim 8 wherein the helical angle of twist of the filaments into yarn is about 15° to 25°.

10. A rope comprising a plurality of strands twisted together, each such strand being formed of a plurality of cords twisted together, each such cord being formed of a plurality of yarns twisted together, each such yarn being formed of a plurality of filaments twisted together, the direction of twist varying alternately in opposite directions from filament to yarn, yarn to cord, cord to strand and strand to rope, the twist of the filaments into yarn making a helical angle of twist of about 15° to 25°, the degree of twist of the yarns in each cord, measured by turns per foot, amounting to about 70 to 85 percent of the turns per foot of the component yarns to effect a balance between the opposing torsional forces manifest between the cord and the component yarns.

11. A rope comprising a plurality of strands twisted together, each such strand being formed of a plurality of cords twisted together, each such cord being formed of a plurality of yarns twisted together, each such yarn being formed of a plurality of filaments twisted together, the direction of twist varying alternately in opposite directions from filament to yarn, yarn to cord, cord to strand and strand to rope, the twist of the filaments into yarn making a helical angle of twist of about 15° to 25°, each yarn twist being structurally balanced against the cord twist, and the amount of twist per unit length in the strands and rope being less than in said cords to provide a twist reservoir in the strands for the acquisition of additional twist from the stresses and strains of service.

12. The rope as set forth in claim 11, wherein said rope is formed of at least three yarns.

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