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ROPES, CORDAGE AND TWINE

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This invention relates to improved ropes, cordage or twines (hereinafter referred to simply as ropes and the like) in particular to ropes and the like constructed wholly or in part from long staple fibers of synthetic polymers.

During the last decade or so man-made fibers derived from synthetic polymeric substances have been used to replace some of the natural vegetable fibers traditionally used for making rope and the like. Hitherto such man-made fibers have been used by the rope or twine maker in the form of continuous filament yarns prepared by the synthetic fiber manufacturer. This arrangement is unfavorable for the rope maker who often requires new and expensive machinery to deal with the new yarns and whose preparing machinery, designed for use with the natural fibers, is made obsolete.

Although the man-made synthetic fibers in general possess superior strength and abrasion resistance compared with the natural vegetable fibers, they are considerably more costly than the natural fibers and, in the form of ropes and the like made of continuous filaments, have a number of disadvantages. For example the slippery feel is unattractive in use, particularly to those accustomed to handling vegetable fiber ropes and the like.

A more serious disadvantage of all ropes made wholly from synthetic filaments is in situations where friction is likely to develop heat sufficient to soften or melt the individual fibers. Under these conditions the surface of the synthetic filament rope becomes smooth and glazed and the rope useless for its proper function.

We have found that much improved ropes and the like may be prepared from synthetic polymeric substances if these are spun into continuous filaments of appropriate thickness and then cut into suitable lengths prior to making the rope yarns and the ropes therefrom.

According to our invention we provide a process for the production of ropes and the like composed of 20 to 100% by weight of synthetic fibers and 0 to 80% of long vegetable fibers comprising spinning the rope yarn from a mixture of the said fibers and constructing the ropes and the like in the usual way, characterised in that the synthetic fibers are cut to a length between 25 and 80 inches and have a thickness between 0.001 and 0.020 inch.

The process of our invention offers a number of advantages over processes already described for producing ropes and the like from either natural long vegetable fibers or continuous synthetic filaments. One of the most important advantages is that the synthetic fibers of our invention may be processed, either alone or mixed with the natural fibers, directly on the usual machinery used for preparing and spinning natural long vegetable fibers into yarn and for this reason blending with the natural fibers to produce a uniform yarn is simply effected. Furthermore by the process of our invention it is possible, without any modification of the conventional process to produce a yarn of the approriate size for construction of twine, cord or rope, whereas with continuous filament yarns of synthetic polymers a number of additional plying operations are required to produce an adequate yarn.

In the production of ropes and the like a number of plying-with-twisting operations are required. In each of these operations, because it is undesirable or impossible to twist the structure sufficiently to completely prevent slippage of individual fibers over one another under tension, some of the inherent strength of the fibers comprising the structures is lost. An important advantage of the process of our invention is that this loss of inherent strength is substantially lower than that incurred in constructing ropes either from natural long vegetable fibers, as for example sisal or manila, or from continuous filaments of synthetic polymers. This reduction in lost strength, by the process of our invention occurs mainly at the first plying stage, that is, at the stage of preparing the twine or rope strand from the rope yarn and the improvement is carried through to the final structure.

In a satisfactory rope it is desirable that the extension of the rope at the safe working load (usually about 20% of the breaking load) should be about 5%. However, as the extensibility of synthetic fibers is, in general, appreciably higher than that of the natural fibers, ropes and the like made from continuous filaments of synthetic polymers usually have an extension of very much greater than 5% at the safe working load. Several attempts have been made to overcome this short-coming of synthetic continuous filament ropes by special constructions of the rope such as are described in British Patent 811,501 and U.S. Patent 3,055,167. Also by reason of the very different extensibility of natural and synthetic fibers ropes constructed from yarns comprising natural fibers on the one hand and synthetic filaments on the other fail easily when stretched by fracture of the less extensible natural fiber yarns composing the rope. We have found that by constructing the rope according to the present invention, the extensibility of the final rope is brought down to the desired value. The following table which gives the properties of typical ropes of three inches circumference prepared from polypropylene in continuous filament (5 denier per filament) and long staple (40 inches long and 0.005 inch diameter) forms illustrates the improvement obtained by the process of the present invention.

Fiber	Extension at safe working load (percent)	Extension at break (percent)
Continuous filaments	14	36
All long staple fibers	9	30
50/50 sisal/long staple fibers	4	27
65/35 sisal/long staple fibers	3	13
All sisal	4	12

We have also found that ropes and the like prepared according to our invention from mixtures of natural and synthetic fibers have a number of advantages over those prepared from all natural or all synthetic fibers. For example blending of the natural fibers with the stronger synthetic fibers improves the strength of the product over that of a comparable all vegetable fiber product, to an extent dependant upon the proportion of synthetic fibers used. Although this increased strength would be expected to lead to a proportional increase in the life of the rope in use, we have found, surprisingly, that ropes and the like, made by the present process have a life greatly in excess of this expectation. For example, a four strand rope of 3¾" circumference made according to this invention from a 50/50 mixture of sisal and isotactic polypropylene (40" staple length 0.005" diameter fibers) has 20% less weight per unit length than an equivalent size of all sisal rope together with a 25% improvement in strength. This sisal/polypropylene rope in use as a quarter rope in deep sea trawling operations gave a lifetime of 6 to 8 times that of the all sisal rope, very much in excess of expectation. In another usage two ropes of similar size were compared in use as tail ropes in river barge towing which are subject to high abrasion together with alternate wetting and drying cycles. One rope was all sisal and the other 50/50 sisal/polypropylene. The mixed rope gave a life of 6 times that of the all sisal rope.

A further advantage of the blended natural/artificial fibre ropes of the present invention is that such ropes do not swell to the same extent as all natural fiber ropes. Such swelling when the rope is subjected to successive wetting and drying cycles leads to unlaying of the natural fiber rope structure with consequent reduction of abrasion resistance and life. This effect is substantially absent in the ropes of the present invention due to their reduced swelling propensity.

Also as some synthetic fibers, in particular those produced from stereoregular polyolefines, have a low density, the density of the product may be controlled by adjustment of the proportions of natural and synthetic fibers, so that the product will sink or float in water as desired. Ropes and the like constructed from a blend of natural and synthetic fibers do not suffer from the deficiency of forming a glazed or smooth surface when subjected to frictional heat, for the natural fibers serve to keep the fusible synthetic fibers apart and so prevent the formation of a continuous glazed surface. In this case also the water retention of the wet natural fibers is often sufficient to assist cooling or lubrication of the rope and further prevent fusing of the synthetic fibers.

In order to assist preparation of the fiber blend and the spinning of the blend, in particular the separation of the synthetic fibers after compression into packages, we have found that it is desirable, if the cross section of the fibers is substantially circular, to impart a small amount of crimp to the synthetic fibers of about 5–20 percent crimp as expressed by the relation

$$\frac{L_2-L_1}{L_2}\times 100$$

where L_1 is the length of the filament with the crimps present and L_2 is the length of the same filament when extended just sufficiently to remove the crimps. We have also found that changing the cross-sectional shape of the synthetic fibers has a beneficial effect on the ease of processing the fibers, alone or mixed with natural fibers into ropes and the like. Thus if fibers having a more or less flattened cross section, as for example rectangular or square sections, are used there is no need to impart crimp to the fibers in order to improve the ease of processing. Whatever the cross-sectional shape given to the synthetic fibers it is essential that the thickness should be between 0.001 and 0.020 inch. By thickness is here meant the diameter of a circular fiber or any linear cross-sectional dimension of non-circular or flattened fibers. Fibers having a rectangular cross-section in which one dimension is about three times the other are particularly suitable.

Natural fibers suitable for use in the process of our invention are any of those usually called long vegetable fibers and commonly used for production of ropes and the like. Among the most useful natural fibers are hemp, manila and sisal and of lesser importance are ramie and flax in the longer forms.

The choice of synthetic fiber is governed to some extent by economic factors but it is possible to use many of the commercially produced synthetic fibers in the process of our invention and we have found that fibers prepared from stereoregular polyolefines, polyesters or copolyesters polyamides, polyvinyl chloride, polyvinyl alcohol or acrylic polymers are very suitable. The very high strength coupled with low density and moderate extension make the fibers prepared from isotactic polypropylene very suitable for use in the process of our invention.

The natural and synthetic fibers are combined in as uniform a manner as is practical in the spinning operation to produce the yarns and when the rope or the like has been completed no after treatment by heat is necessary to stabilise the lay of the rope, such as is necessary when a rope is made entirely of continuous synthetic filaments.

In a specific embodiment of our invention we have prepared a rope of three inches circumference from a 50/50 blend by weight of sisal and isotactic polypropylene fibers, the latter having a length of 40 inches, a diameter of 0.005 inch, and a tenacity of 7.0 grams per denier. When this rope was subjected to a load equivalent to 75% of its breaking load, that is to a load of 3.9 tons, it was found upon close examination after releasing the load that the sisal fibers, which originally had a length of about 40 inches, were broken into short lengths of 1–2 inches corresponding approximately to the distance between successive turns of the polyproylene in the twisted yarn. Thus it is apparent that the greater extensibility of polypropylene (18% approximately compared with 2% for sisal) enables greater utilization of the strength of the natural fiber before the latter is destroyed and the synthetic fiber assumes the full load. By comparison an all sisal rope stretched to breaking point will exhibit a transverse fracture in which substantially all the fibers have broken at one point.

The following table illustrates the properties of ropes, all 3 inches circumference, prepared on conventional long vegetable fiber spinning and rope laying machinery from the synthetic fibers and blends of the present invention. Also included for comparison are the properties of ropes of the same size constructed from natural fibers or continuous multifilament synthetic fiber yarns.

Fiber	Fiber tenacity, g./den.	Rope yarn tenacity, g./den.	Rope		Weight, lb./120 fathoms	Conversion efficiency, percent	
			Tenacity, g./den.	Strength, tons		Fiber to rope yarn	Fiber to rope
1. All polypropylene, 40 x 0.005 inches diameter	7.0	6.9	3.4	9.4	156	99	49
2. 50/50 Sisal/polypropylene 40 x 0.005 inches diameter	----------	3.6	1.8	6.0	186	90	45
3. Manila	5.1	2.5	1.2	[1] 4.5	206	50	24
4. Sisal	4.0	2.2	1.0	[2] 4.0	206	55	25
5. Polypropylene multifil. 5 d.p.f	8.0	6.0	2.9	8.0	143	75	37
6. Polyethylene terephthalate multifil, 5 d.p.f	6.0	4.0	2.0	8.0	223	67	33
7. Nylon multifil, 5 d.p.f	8.0	6.0	3.0	11.0	194	75	37
8. Polyethylene, 0.010" diam. mono	6.0	4.4	2.2	5.5	143	73	37

[1] Minimum for B.S.S. Grade 1.
[2] Minimum B.S.S. value.

In this table conversion efficiency is the ratio of breaking strength, for example of the rope yarn, to that of the initial fibers expressed as a percentage. The size of the filaments comprising the multifilament yarns is expressed in the usual way as denier per filament of d.p.f.

From the table the improvement in conversion efficiency obtained in ropes made according to our invention, that is Examples 1 and 2, is clearly evident.

What we claim is:

1. Ropes and the like composed of spun rope yarn which is 20 to 100% by weight of synthetic fibers blended with 0 to 80% of long vegetable fibers, said synthetic fibers being cut of length between 25 and 80 inches and having a thickness between 0.001 and 0.020 inch.

2. Ropes and the like according to claim 1 wherein the synthetic fibers are selected from the group consisting of stereoregular polyolefines, polyesters, copolyesters, polyamides, polyvinvyl chloride, polyvinyl alcohol and acrylic polymers.

3. Ropes and the like according to claim 2 wherein the stereoregular polyolefin is isotactic polypropylene.

4. Ropes the like according to claim 1 wherein the long vegetable fibers are selected from the group consisting of hemp, manila, sisal, ramie and flax.

5. Ropes and the like according to claim 1 wherein the synthetic fibers are crimped and have a substantially circular cross-section between 0.001 and 0.020 inch diameter.

6. Ropes and the like according to claim 1 wherein the synthetic fibers have a more or less flattened cross-section.

7. Ropes and the like according to claim 6 wherein the synthetic fibers have a substantially rectangular cross-section in which one dimension is about three times the other.

8. Ropes and the like according to claim 5 wherein the crimp of said synthetic fibers is about 5–20% as expressed by

$$L_2 - L_1(100)/L_2$$

where L_1 is the length of the filament with the crimps present and L_2 is the length of the same filament when extended just sufficiently to remove the crimps.

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MERVIN STEIN, *Primary Examiner.*