Development of a Braided Polypropylene Rope Using Polypropylene Tape Yarns

M. Moyo, L. Nkiwane, J. A. Nyathi, A. B. Nyoni

National University of Science and Technology
Department Of Textile Technology
P.O. Box AC 939, Ascot, Bulawayo
ZIMBABWE
mufaro.moyo@nust.ac.zw / mufaromoyo@gmail.com

Abstract

Traditionally, braided ropes are manufactured using either staple yarns or multifilament yarns. This study therefore sought to break this traditional paradigm by uniquely and economically manufacturing braided polypropylene ropes using polypropylene tape yarns. A recipe made up of virgin polypropylene granules, calcium carbonate and black masterbatch was used to produce a polypropylene plastic sheet, which was extruded on a Barmag machine. Tape yarns with a width of 22 mm on average were produced. Count, width, thickness, elongation and tensile strength of the tape yarns used to produce the rope were tested. The elongation and tensile strength tests were done on a Micro 500 Testometric strength-testing machine. Test results on the tape yarns revealed that they have properties that fall within the standard range of fibrillated polypropylene tape yarns. Sorptive properties of both the tape yarns used and the braided rope developed revealed a slight increase in water absorbance to approximately 0.15% compared to standard water absorbance of less than 0.1%. This increment in water absorbance, however, did not change the floating properties of both the tape yarns and the braided rope as they both remained with their positive buoyancy. Also, no signs of microbial attack were seen on the tape yarns and the braided rope by naked eyes after exposing the samples to water. The resultant braided rope produced was made up of 12 X 4973 denier polypropylene tape yarns with a 9200-denier polypropylene bailer twine as the core. The count and diameter of the resultant rope were found to be close to those of hazard barrier and hydro-pulling ropes and were also analogous to those of 5 mm cotton braided ropes produced.

Keywords: Polypropylene, tape yarn, braided rope

1. INTRODUCTION

Traditionally, braided ropes are made from staple yarns, mono- and multi- filament yarns. Endeavours to produce braided ropes using tape yarns have never been made. This study investigated if braided ropes can be made from polypropylene (PP) tape yarns. Presently, tape yarns are being used in the production of extruded, woven and knitted products such as polypropylene woven bags, nets, bailer twines and thatching twines.

The purpose of the study was to diversify production of ropes by braiding which in Zimbabwe have only been produced using natural fibres. Polypropylene is a very light filament, which results in ropes that are easy to carry. It can be engineered to possess improved mechanical and chemical properties that lead to production of PP ropes which are lightweight, with a substantially higher strength to weight ratio. Non-biodegradable, polypropylene satisfies four requirements of the Environmental Commission (EC) namely, [1, 2]:

a) minimum use of natural resources,
b) reduced emission of polluting substances,
c) long working life, and
d) optimized re-use and recycling.

Industrial processing of PP is cleaner than that of natural fibres which liberate large amounts of fluff and other debris during their processing. These are detrimental to the operators' health, machines and the

Published 2014

environment and hence require extra-equipment for dust extraction [2].

In order to enable the development of a braided polypropylene rope there was need to do the following:

i) extrude a polypropylene plastic sheet from virgin polypropylene polymeric granules mixed with calcium carbonate and masterbatch;
ii) form PP tape yarns by slitting the extruded PP plastic sheet according to width and denier;
iii) produce a braided PP rope and perform quality testing;
iv) produce design specification for both the tapes and the braided PP rope.

2. METHODOLOGY

Figure .1 shows the flowchart for the production of braided rope from polypropylene tape yarns.

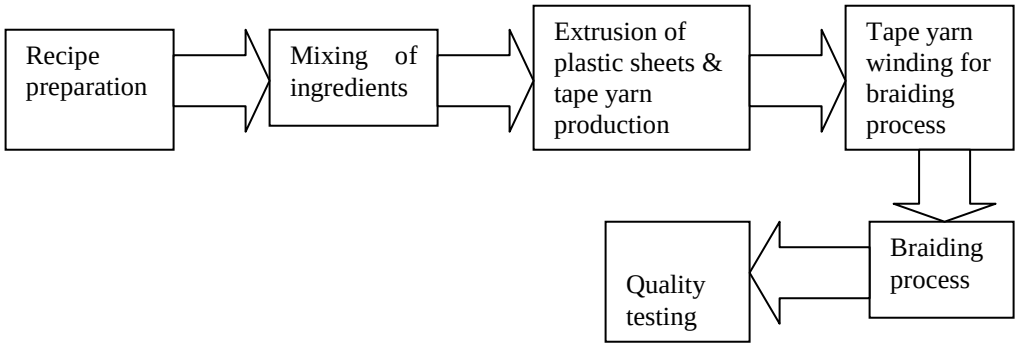

Fig 1 Production flowchart for braided polypropylene rope

The recipe was prepared with the following constituents:

~25kg HKR 102 virgin Polypropylene polymer granules (97.9%),
~125g calcium carbonate (0.5%),
~400g black masterbatch (1.6%).

The ingredients were poured into a drum that was electrically turned three times before extrusion of the plastic sheets to promote intimate mixing of the ingredients. The mixture was poured into the hopper of the Barmag extrusion machine for processing and the extruder parameters were as follows:

~Barrel temperatures of 150^{o}C, 165^{o}C and 185^{o}C in zone 1, zone 2 and zone 3 respectively,
~Filter temperature of 220^{o}C (Heat Zone 4),
~Off-set block temperature of 220^{o}C (Heat zone 5), and
~Die-head temperature of 220^{o}C for all the three heating zones.

A plastic sheet was extruded and cooled in a water bath using a water-quenching technique. The temperature of the cooling water was maintained at 27^{o}C.The plastic sheet was then slit into five tape yarns immediately after the quenching process using razor blades which were placed 22 mm away from each other. The tapes were then drawn, stretched and heated with hot dry air so as to anneal and align the stressed polymer molecules in a crystalline state. The formed tape yarns were wound onto plastic tubes and then unwound onto 12 braiding bobbins on a Herzog winding machine. Each braiding bobbin had 220m long tape yarn.

Published 2014

The braiding bobbins were creeled on a 12 carrier Ratera circular braiding machine. The combination of braiding gears chosen was 40, 32 (inner gear), 21 (outer gear) and 27. A bailer twine of 9200 denier was used as the core material. Fifty metres of braided polypropylene rope were produced and then taken for quality testing. Quality tests were done on both the tape yarns and the braided rope. A Micro 500 Testometric Testing Tensile Strength testing machine was used for testing tape yarn strength and elongation. Thirty metres of braid was cut and into three braid pieces each of 10m, and the following properties tested at ambient temperatures: count, width, thickness, tensile strength and elongation. Water absorbency tests were also conducted on two tape yarns and one-braid sample with known dry mass. These were immersed in water and left for one week in a cabin after which they were removed and their new mass measured.

3. RESULTS AND DISCUSSION

3.1. Introduction

Tape yarns suitable for rope production were extruded and successfully used to produce polypropylene ropes by the braiding method. Figure 2 shows pictures of the developed tape yarns and the braided ropes.

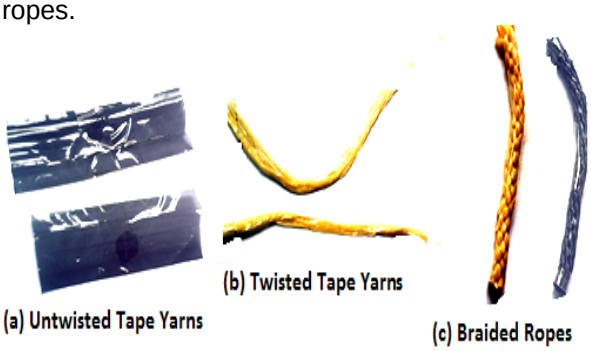

Fig 2: Developed tape yarns and the braided ropes

Figure 2(a) shows untwisted tape yarn samples and Figure 2(b) shows twisted tape yarn samples of the extruded yarns. Figure 2(c) shows the braided ropes that were produced using the twisted tape yarns.

3.2. Extruded tape yarns

Table 1 shows the arithmetic mean and the standard deviation for the tape yarns properties tested.

Table 1 Arithmetic Mean and Standard Deviations for Tape Yarns

Property	Arithmetic mean	Standard deviation
Mass in grams	0.55	0.0278
Count in denier	4 973	-
Width in mm	22	0.587
Thickness in mm	0.028	0.00126
Tensile strength in gf/den	3.76	0.303
Elongation at break as a %	11.32	1.48

The standard deviations (SD) for all the properties were very small as shown in Table 1 indicating that there were extremely small variations in all the twenty tape yarn specimens. The SD for count was given by that of mass because the mass was the only variable determining count since the length was kept constant. Whatever variability occurred to mass was transformed to count variability. On comparing the count, tensile strength and elongation at break of the developed tape yarns with available types of polypropylene tape yarns, it emerged that the developed tape yarns had count, tensile strength and elongation at break properties that fell within the range for fibrillated polypropylene tape yarns as shown in Table .2.

Published 2014

Table 2 Developed tape yarns, Flat yarns and Fibrillated Properties

Property	Range for Flat PP tape yarns	Range for Fibrillated PP tape yarns	Produced PP Tape Yarns
Count in denier	360-3600	630-13000	4973
Tensile Strength (gf/den)	4.5-6.8	3.4-5.1	3.76
Elongation at break (%)	15-30	7-15	11.32

Even if the developed tape yarns were not fibrillated during the extrusion process, their count, tensile strength and elongation at break properties resembled those of fibrillated ones (Table 2). This implies that the molecular form of PP was not significantly changed during extrusion. This may also be an indication that the additives used (calcium carbonate and black masterbatch) did not cause significant changes to the polymeric chain of polypropylene. The average thickness of the developed tape yarns was found to be 28 microns and it falls within the standard range of 22-90 microns [1]. It specifically falls within the thickness standard range for warp knitting tapes with a thickness range of 0.02-0.03 mm [1]. The width of 22 mm falls within standard range for bailer twines with a width range of 20-60 mm [1].

3.3. Developed braided polypropylene rope

Table 3 shows average results of length, diameter, mass and linear density (count) of the developed rope and the associated standard deviations.

Table 3 Properties of the developed rope

Property	Length (m)	Diameter (mm)	Mass (g)	Count (denier)	Count (tex)
Arithmetic mean	10	6	133.8	120457	13384
Standard deviation	0	0.02	0.383	-	-

The small standard deviations for both the diameter and mass implied a very small variability amongst the recorded values. This meant high uniformity of the count and diameter of the braided rope along its length.

The count of the braided polypropylene rope of 13384 tex was found to be typical to 5 mm cotton braids of 13 300 tex ± 100 [5]. The results showed that the count of 13384 tex was close to that of hazard barrier and hydro-pulling ropes with a count of 13 350 tex [5, 8]. The 6mm diameter of the produced rope was found to be very close to that of hazard and hydro-pulling ropes with a diameter of 6.4 mm [4, 8].

3.4. Water absorbance of tape yarns and the rope

Table 4 shows water absorbency results of the tape yarns and the braided rope.

Table 4 Water absorbance of tape yarns and rope

Property	Tape Yarn Sample 1	Tape Yarn Sample 2	Braided Rope
Dry mass (g)	0.2399	0.2469	6.7012
Wet mass (g)	0.2332	0.2473	6.7113
Mass of absorbed water (g)	0.0003	0.0004	0.0101
% water absorbed	0.13	0.16	0.15

Published 2014

Percentage of water absorbed by the tape and the braided polypropylene rope was found to be above 0.1%. Pure polypropylene fibre absorbs less than 0.1% water at 65% relative humidity and 20ºC [4]. The slightly higher absorbency was presumably due to calcium carbonate, which absorbs water as well as disruption of the dense packing of polypropylene polymer by calcium carbonate and pigments used as masterbatch. The calcium carbonate molecules are mechanically entrapped into the PP polymer and this disrupts the dense molecular packing in the PP fibre. This disruption reduces the hydrophobicity of the polymer and increases its hydrophilicity instead. The percentage water absorbency for the braided rope was analogous to that of its constituent tape yarn. This was expected since no additives were used during braiding. Even though there was an increment in water absorbance ability of the tape yarn, this did not significantly change the density of both the tape yarns and braided rope. They still remained with their positive buoyancy. No signs of microbial attack were seen by naked eyes after exposing it to varying atmospheric conditions for a week.

Masterbatch was used so as to give colour to the rope. Production of coloured ropes from natural fibre yarns is an expensive endeavour due to the need for wet dyeing of yarns. This also lengthens the production process. Coloured ropes are not usually manufactured using yarns spun from natural fibres because it is expensive. Dope dyeing which is a relatively cheaper way of dyeing PP than wet dyeing of natural fibres makes production of coloured ropes more economical. Dope dyeing also results in good colourfastness properties. The polypropylene tape yarns were manufactured using a dope dyeing system [4].

4. CONCLUSION AND RECOMMENDATIONS

4.1 Conclusion

A braided PP rope was successfully developed using PP tape yarns. The construction of the braid followed a 12 X 4973 denier PP tape yarn and 920-denier bailer twine core. The braided rope count of 120457 denier and diameter of 6mm were found to be close to those of hazard barrier and hydro-pulling ropes with a diameter of 5mm and an average count of 130000 denier [8], and also analogous to cotton braided ropes. [5]. Therefore, it was concluded that when properly manipulated, polypropylene tape yarns are suitable for use in the production of braided polypropylene ropes. Thorough testing of strength and elongation for the braided polypropylene would be necessary. The following properties together with market research and cost-benefit analysis are recommended areas for further research.

i) Since polypropylene is not resistant to ultra-violet light, the inclusion of ultra-violet stabilizers in the recipe is recommend [6,7]. Also, oxidant additives should be used during the extrusion process so as to make polypropylene braided ropes more biodegradable augmenting its photon-degradability.

ii) PP is not resistant to ultra violet (UV) radiation. For PP ropes intended for outdoor use, incorporation of UV stabilizers is recommended. Treatment by UV stabilizers is done during the extrusion process where the UV stabilizer is included as one of the recipe ingredients [4].

iii) The braided polypropylene ropes can be used to replace cotton agricultural twines, which need chemical treatment to make them resistant to microbial attack. The replacement of these twines with microbial resistant and poor host for bacterial growth polypropylene braids would be a simple and economical answer to the problem of using cotton twines for agricultural applications.

iv) Suggested uses of the rope include use as hydro-pulling rope, rescue rope, water-ski rope for younger children, agricultural applications, aquatic applications and general tying [8].

4.2. Recommendations

In rural areas, PP ropes can find such uses as in fetching water from wells, in farm applications or general tying of goods, since the product has no problems when used under humid conditions. Some rural communities engaging in basketry may find PP yarns a good substitute for 'ilala' palm, which is difficult to dye to a wide range of colours. Dope-dyed PP can be produced in a wide range of colours. Table 5 shows the recommended design specification for the production of PP tape yarn and rope.

Table 5 Recommended design specification for PP tape yarns and rope

Product	Property	Specifications
Tape PP Yarn	Count (denier)	4 973±100
	Width (mm)	22±2
	Thickness (mm)	0.028±0.005
	Elongation (%)	11.32±10
	Tensile strength(gf/den)	3.76±0.81
Braided PP yarn	Count (denier)	120 457±650
	Diameter (mm)	6.00±0.05
	Tensile Strength (gf/den)	Not measured
	Elongation(%)	Not measured
Bailer Twine core	Count (denier)	9.200±100
	Tensile Strength (gf/den)	2.51±0.1

REFERENCES

[1] Trade Information. *Lenzing Plastics* GmbH and Co.KG, United Kingdom, 2002.

[2] Wulfhorst, B.M.K., *Polypropylene Fibres,* Chemiefarsern/Textilindustier, 1989, 39/91, E173-E176

[3] Pandit, K., and Sett, S., *Yarn From Film, A New Manufacturing Technique Man Made,* Text, India, 1990, (pp83-86).

[4] Philips. K.J., and Gosh T.K., The *Technology of Polypropylene Tape Yarns: Processing and Applications,* Textile Progress 33, (1), United Kingdom, The Textile Institute International, 1980 (pp. 58-64)

[5] *Twine and Cordage*; Harare, Zimbabwe, (unpublished). Production and Product specifications, 1999.

[6] http://www.prestoncord.com/page3 [Viewed October 2008]

[7] Heath R.J (editor); *Progress in Rubber and Plastics Technology,* RAPRA Technology Ltd., United Kingdom, Vol.15, No.2, 1999 (pp. 69-74)

[8] NOVABRAID Catalogue available on www.novabraid.com [Viewed October 2008]