Recycling of metallic cut-resistant yarns

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Introduction

Cut-resistant protective textiles are most commonly used to provide protection against mechanical hazards, such as cut, slash, lacerations while working at manufacturing units and also by security forces or street wardens (1-7). Metallic components such as stainless steel, tungsten are used in combination with high performance fibres such as Aramid, Ultra High Molecular Weight Polyethylene fibres to manufacture technical composite yarns which are knitted, woven or braided to develop cut-resistant textiles such as gloves, sleeves, balaclava, socks, garments/uniforms (8-18). Although, the market of cut-resistant metallic yarns continues to grow in the area of protective and electronic textiles, there are no established sustainable solutions available to recover and recycle post-consumer and post-industrial cut-resistant waste metallic yarns. During manufacturing process, these waste metallic yarns are created which can't be recycled using traditional methods of textile recycling. As a result, the waste metallic yarns end up in the landfill (Figure 1,2,3). Further, the commercially available cut-resistant gloves manufactured using steel wire in core are also dumped into landfill after multiple usage (Figure 4).

The present invention provides a process of reusing waste metallic yarns which alleviates the waste disposal problems. It can also be used to recycle metallic core cut-resistant gloves after the end of the life cycle (19). This would in-turn address a variety of issues including, but not limited to, fire accidents or mishaps, high processing costs, environmental concerns such as environmental pollution and harmful chemical treatments. Moreover, this would also provide a process of managing waste metallic yarns which has the potential to contribute significantly to the alleviation of waste disposal problems by reusing or recycling the waste metallic yarns thereby preventing environment damage and pollution.

Figure 1. Spinning waste of High Performance Polyethylene Fibres (UHMWPE) twisted with 50 micron of stainless steel

Figure 2. Metallic Aramid yarn waste generated during automatic clearing & winding

Figure 3. Knitted gloves waste using aramid/wire and UHMWPE/wire yarns

Figure 4. Examples of commercially available cut-resistant gloves made using steel wire in the core

Manufacturing process & stages of waste creation

Various high performance fibres such as Para-aramid (25-35 USD per kg), Meta-aramid (15-20 USD per kg), Ultra High Molecular Weight Polyethylene fibres (USD 12-30 USD per kg) are used for manufacturing cut-resistant yarns. In order to achieve higher cut performance, these yarns are reinforced with stainless steel wire (30-70 microns), glass , basalt filaments or even Tungsten wire (20-40 micron) in core. The metal components are hidden inside yarn so that they are not in contact with skin. This is done to prevent skin irritation to the end users. Recently, higher proportions of steel, tungsten, copper and other metallic wires have been used to spin textile yarns to achieve cut-resistance, antistatic properties or even for shielding of electromagnetic waves. These yarns are costly owing to the extremely high price of the fibres and metals used in the manufacturing process. During the spinning process of such conductive yarns, the textile process waste obtained is discarded as landfill owing to the presence of conductive components in the core of the such cut-resistant metallic yarns. Table 1 shows process flow-chart and different stages where metallic waste yarns are created which can’t be recycled using traditional processes. So, they’ve to be dumped in landfill even though raw materials are very costly. Additionally, these metallic waste yarns are also generated during seamless knitting of cut-resistant gloves (Figure 3) or weaving of cut-resistant fabrics.

Table 1. Process flow-chart: Manufacturing of cut-resistant yarns

Twisting Machine for filaments		Ring Spinning for staple fibres	
Conversion of bigger packages of UHMWPE/Aramid filaments into smaller bobbins to run on twisting machines	Waste can be reused	Conversion of staple fibres to sliver (Blowroom & Carding);	Waste can be reused
Twisting with steel wire in core	Waste can't be reused	Sliver to roving (Drawframe & Speedframe	Waste can be reused
Change of packages while using new wire spools	Waste can't be reused	Core spinning with steel wire (Ring frame);	Waste can't be reused
Smaller packages rewound to bigger packages	Waste can't be reused	Automatic Winding & Splicing to bigger packages;	Waste can't be reused
Splicing waste	Waste can't be reused	Plying using TFO.	Waste can't be reused

Traditionally, textile recycling machines for cutting, opening, garneting, or carding are used to convert spinning yarn waste into fibres which are further spun into yarns after recycling. The conventional machines cannot be used to recycle conductive core metallic yarns due to the risks involved of fire accidents. The conductive cores being metallic in nature can not only damage circuits but also can cause fire sparks during recycling. For this reason, most of the waste metallic yarns and gloves made from these yarns are discarded in landfills; although upto 60 percent of staple fibres present in these metallic waste yarns can be reused to reduce carbon footprint. It is worthwhile to mention that the textile waste thus obtained is way more than the allowed limits of genuine waste being produced which again leads to dumping of such large amounts of the textile waste in landfills. The large amounts of waste metallic yarns discarded in landfills add to the global problems of waste disposal and can create further environmental issues.

Innovation Defined

This paper demonstrates a unique way of processing metallic conductive waste which can be re-used for protection against thermal & mechanical hazards or for protection against electromagnetic waves. The process discussed in the current disclosure involves management of the waste metallic yarns by recycling these yarns to form various articles of different sizes and shapes which may be then used for various applications. The articles thus obtained may be further coated to create smooth surfaces of such articles. The articles may include, but are not limited to, ball, rope, curtains, or the like. Figure 5 illustrates the pictorial image of the exemplary article formed from the waste metallic yarn with & without coating; and Figure 6 illustrates pictorial image of the another article formed from the waste metallic yarn both prior and after coating.

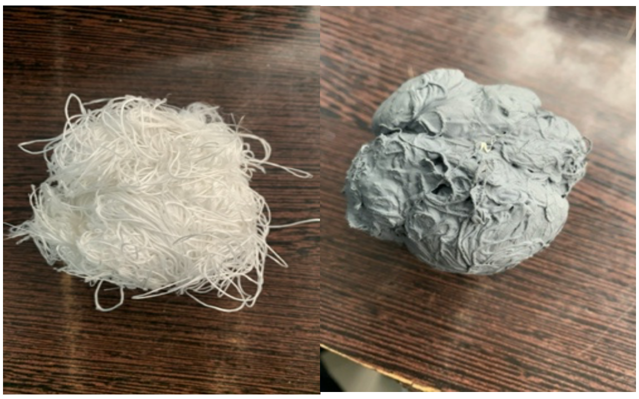

Figure 5. Spherical structure created using metallic waste yarns of UHMWPE

Figure 6. Rope structure created using metallic waste yarns

The process comprises procurement of waste metallic yarns from various fields of textiles such as, but are not limited to, conductive textiles, electronic textiles, filtration fabrics, fashion industry, or the like. The waste metallic yarns generally include high performance fibers/yarns whose performance degrades with long term use and are considered as waste. These waste metallic yarns may be processed or converted into various articles of different configurations in terms of different sizes and shapes or dimensions depending on the requirement or use of the article. The waste metallic yarns may be combined together, for example, interlaced, stitched, glued, braided, or woven to create two dimensional or three dimensional structures or articles. For example, waste metallic yarns may be entangled together to form a ball or a rope, as shown in Figure 5 and 6, respectively. These articles of various dimensions may be further coated with materials such as, but not limited to, polyurethanes, latex, nitrile or any other compounds to remove any protruding yarns, fibres, wires from these articles which eliminates or reduces the risk of any kind of injuries or cuts by the usage of such articles. The coating helps in obtaining smooth surfaces of these articles which are easy and safe to handle or operate. Further, the coating adds on to the aesthetic appeal or various colours of the article or the product.

Owing to the presence of high performance fibres/yarns, the articles made from waste metallic yarns possess much better strength, abrasion properties or like in comparison with the ordinary textile yarn or fibre. Therefore, such articles may be used in various applications

(21-24). For examples, balls (spherical structure) made from these waste metallic yarns having metallic core may also absorb heat when introduced with microwaves. Other applications for these articles include, but not limited to, impact, stab or puncture resistance, EMF shielding, microwave absorbent textiles, fire-resistance in curtains or other items, heating or cooling pads for therapy, or the like. The process of managing waste metallic yarns by forming various articles could also help in reusing and recycling of the waste metallic yarns which thereby eliminates the need of discarding such waste yarns in landfills and reduces the environmental pollution. This would further save raw materials used or invested in preparing such articles which can be made from the waste metallic yarns thereby reducing the use of virgin raw materials for preparing these articles or products. Currently, the fibre component may be manually segregated from the waste metallic yarns for recycling and to be used in preparing further textiles or fabrics. The cost of manual segregation of these high valued metallic waste yarns can be justified in the low-cost economies where labour cost is 200-250 USD/month whereas the cost of raw materials utilised are in the range of 25-50 USD per kg. Assuming each labour can process upto 20 kg of metallic waste yarns every day which equates to 520 kg every month or 15000 USD worth of raw materials recycled every month by an individual labour.

Conclusions

The metallic waste generated during manufacturing of protective textiles (yarns, gloves, fabrics) can be recycled to develop variety of structures which can be used as:-

- Impact, stab & puncture resistant articles;
- reinforcement of structures;
- automotive or building insulations;
- panels for fire barrier;
- EMF shielding panels;
- microwave absorbent textiles.

Further work is being done to develop semi-automatic or automatic methods to segregate and process metallic waste textiles. Various coating methods and techniques also being studied using water based polyurethane, latex, silicone, nitrile to achieve chemical and water repellency alongwith variety of colour options.

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