Manufacturing of Cut Resistant Gloves

1. Introduction

The world market demand of all categories of protective gloves including cut resistant is increasing day by day. Total annual worldwide demand of protective gloves is estimated near about 13.5 billion pairs. Demand of protective gloves split among Europe, North America, Asia and rest of the world is about 20 to 30% of total consumption.

Accidents involving the use of sharp objects make up a significant percentage of injuries in the workplace (the exact percentage varies from industry to industry; with shop-floor workers are most likely to suffer injuries of this nature). More than 80 percent of all hand injuries are due to cuts. Most of which can be traced to an absence of gloves, that's why there is a good demand of protective gloves that not only resist cuts, but are also comfortable to wear, ensuring compliancy as well as safety.

Glove manufacturers are continually looking for new and ingenious combinations of materials to achieve the greatest protection possible, whilst still allowing the wearer enough dexterity to perform the intended activity. Generally, Dyneema and Spectra, glove can be used for protection against higher levels of risks against cut and puncture hazards. It has been seen that gloves made from Dyneema/nylon blended yarn can provide high level of protection against cuts with good wearing comfort. This report suggests the Dyneema/nylon blended yarns for gloves materials & seamless gloves knitting machine for gloves manufacturing.

The use of yarns with high cut-resistance properties in knitted gloves, including some that are woven with stainless steel wire threads, have proved to be of great benefit. The aim of proposed project is to develop cut resistant & abrasion resistant protective textile by using composite metallic yarn. To study the cut resistant & abrasion resistant properties of protective textile 60 micron steel filament has been used as a core and nylon, polyester and cotton fibers, are used as sheath fibers to cover the steel filament and was spun into 10s count yarn on DREF machine and tested for their physical properties. The knitted gloves and woven fabrics were prepared by using these yarns, and were tested for their physical, cut & abrasion resistant properties. Techno economic viability of the developed products has also been worked out.

1.1 Demand & Supply

In 2006, total industrial demand for protective gloves amounted to € 1,972 million. The market size grew 2.9% annually during the period 2003-2008 and a further growth of the same level is expected in 2009 and 20011.

The share of developing country imports increased 20% (in absolute terms) to 68% of the EU imported value of protective gloves in the period 2005-2007 and accounted for 95% of imports from outside the EU in 2007. Developing countries, in particular Asian countries dominate EU imports of protective gloves. Malaysia and China (each country 21% of total imports) remained by far the most important suppliers of protective gloves, followed by Thailand (8%), India and Sri Lanka. China dominates EU imports of protective gloves, made of leather, textiles and plastic.

Although all organs are important in human body but hands are a nice and most essential gift of God. The role of hands in almost all routine jobs is most important in life. Hence safeguard of hands is very important. At workplace, during different operations, human body may be exposed to a variety of risks which becomes sever with modern high speed machines.

Fig.1 Cut injuries occurred due to ordinary or simple work gloves

In most of the cases it is human hand which is exposed to risks first and then other body parts. Depending upon the way it happens these risks can be classified in two groups:

1. Hand injuries due to external actions.
2. Risks for people due to actions on the hands.

To protect hands from these risks, it is advisable to use protective gloves. Ordinary and simple work gloves are not suitable for protection towards cut and other mechanical hazards especially in foundries and other meat cutting industries (Fig.1). These protective gloves may be abrasion resistant and cut resistant as per requirements of the job. Other important features of these gloves are good flexibility and gripping ability. These features can usually be found in knitted gloves. Protective gloves produced from Dyneema/nylon blended yarn can full-fill the above requirement but are quite expensive.

The steel core strand prevent fraying and help providing cut and abrasion resistance but the metal strands are conductive for heat and electricity and are not suitable for workers employed in electronic goods manufacturing units and foundries. On the other hand these types of gloves are very much suitable for glass, construction, meat cutting industries workers.

1.2 Glove Category

Various types of hand gloves are available in the market for different end uses as mentioned below.

Disposable Gloves: For single use only.

General Purpose Gloves: For materials handling, maintenance, assembly, inspection and general plant use.

Chemical Resistant Gloves: For material handling in acids, oils, solvents and general utility.

Heat Resistant Gloves: For material handling in hot objects, molten metal, plastic extrusion and heat treating industries.

Cut Resistant Gloves: For handling sharp-edged objects, glass or scrap metal and cutting applications.

1.2.1 Understanding Cut Resistance

Cuts, slices and abrasions account for almost 30% of the lost time and productivity. Most of these (almost 80%) involve hands. Makings sense of cut resistance, however, continues to an allusive task. Knowing the actual level of cut resistance is further complicated by the fact that many glove manufacturers make claims about the level of cut-resistance without having any third party documentation to back up the claims.

Types of Cuts - Most of the hand injuries occur because of reasons mentioned below:

Slicing – Caused by the sliding of the skin across a very sharp edge. The sliding action can be a result of the hand or other skin surface sliding across the sharp edge or by the sharp edge sliding across the stationary hand or other skin surface. Examples of this type of cut would be a slip of the knife when dicing vegetables.

Abrasions – This type of cut is the result of continuous or repeated "rubbing". The surface may or may not be sharp or jagged.

Punctures or impact cuts – These are the result sharp or pointed objects impacting the skin as in a falling pane of glass or sheet of metal. Needle sticks would also fall into this category.

1.2.2 Selection of Cut Resistant Glove

Cut-resistant gloves are designed to protect hands from direct contact with sharp edges such as glass, metal, ceramics and other materials. Cut-resistance is a function of a glove's material composition and thickness. You can increase your cut protection by increasing material weight (i.e. ounces per square yard), using high-performance materials such as Spectra®, Kevlar®, etc., or by using composite yarns made with varying combinations of stainless steel, fiberglass, synthetic yarns and high-performance yarns.

Performance characteristics can also be affected by a materials weight and coatings applied to the outside surface. Lighter weight styles are typically more flexible, resulting in less hand fatigue, while their heavier counterparts will generally provide the wearer with more cut and abrasion protection. Coated gloves enhance grip, especially on slippery surfaces. However, some coated gloves may not be appropriate for food handling applications. The cut resistance gloves are manufactured using different type of fibers for various end uses.

• **Spectra Fiber** - Ultrahigh molecular-weight polyethylene fiber that offers high cut-resistance, even when wet. It's 10 times stronger than steel per unit weight. Spectra gloves are cut and abrasion resistant, often lightweight, flexible and used for food processing, appliance assembly, food service, automotive assembly and the paper industry.

• **Dyneema® -** is a super strong polyethylene fiber that offers maximum strength combined with minimum weight. It is up to 15 times stronger than quality steel and up to 40% stronger than aramid fibers, both on weight for weight basis. Dyneema® floats on water and is extremely durable and resistant to moisture, UV light and chemicals.

• **Kevlar® Aramid Fiber -** five times stronger than steel per unit weight. Inherently flame resistant it begins to char at 800°F (427°C). The thread made of Kevlar fiber is used to sew seams on temperature-resistant gloves. Kevlar gloves offer cut- and heat-resistance. Typically a lightweight flexible material that is used for many applications relating to automotive assembly, sheet metal handling and glass handling.

• **Fiber-Metal Blends -** many durable, abrasion-resistant gloves are made of a woven fabric blend of Spectra, Kevlar and stainless steel.

• **Metal Mesh -** interlocked stainless steel mesh offers superior cut and puncture protection due to its strength. Metal Mesh gloves are very cut- and abrasion-resistant and are used often in meat/poultry applications.

• **Super Fabric® -** Combinations of the number of layers, thickness, substrates, surface coatings, etc., lead to fabrics which have varying levels of puncture, cut and abrasion resistance, grip and flexibility. Tactile surface offers improved grip of wet and oily surfaces.

• **Steel Core** gloves are cut- and abrasion-resistant and are often used for meat/poultry processing, glass handling, metal fabrication, automotive manufacturing as well as being used in the paper industry.

1.3 Manufacturing Process

1.3.1 Knitting of gloves

In gloves making process, yarn packages are used as a feed material. Gloves knitting machine is capable to give seamless gloves and does not require manual stitching.

Fig - Seamless gloves knitting machine

The five finger gloves, with the fingers placed horizontally, are usually produced on specialized knitting machines, equipped with special devices, for producing parts as automatic beginning of the tubular finger, connection between fingers, in order to avoid holes, insertion of an elastic yarn in border structure, patterning the gloves palm, with jacquard pattern i.e., narrowing edges of the tubular palm fabric. Knitting routines for manufacturing knitted glove are explained briefly in forthcoming paragraphs.

The knitting action starts with a piece of fabric which holds the knit during finger production. Knitting action for different parts of gloves is carried out in the order 1-2-3-4-5-6-7-8. During its production, the take down is executed by the auxiliary take down, placed under the needle bed while the main take down is deactivated.

Fingers no 1 to 4 are knitted in a tubular style, knitted one after the other, on the same number of needles but with different lengths. After the index finger production, the connection between the fingers must be executed, in order to avoid the holes. The connection between fingers it is made by cross linking of the loops from each finger edges. Considering that the finger knitting is done on all needles, there are not any free needles at the edges in order to receive a transferred loop. After connecting the finger, palm and thumb finger will be knitted. The connection between thumb finger and palm by knitting a tubular row with split transfer comes next.

The second part of the palm must be fashioned in both edges, by successive narrowing of the tubular knitted fabric. The narrowing takes place by transferring inside the knitted fabric some loops from the two needle beds. In order to get a designed form of the narrowed fabric, some elements should be considered, i.e., the number of the rows between the two narrowing actions, the number of needle steps toward the inside of the fabric at transfer and the number of transferred stitches.

This knitting method permits full automatic knitting of gloves without requiring manual stitching or drawing-in of the leading end of the yarn.

Patterning is also possible on the knitted gloves according to the designer's creativity and machine specifications.

1.3.2 Over Locking the Cuffs of Gloves

A high speed over lock machine is used to perform this function. It features high efficiency, durability, Convenience and so on.

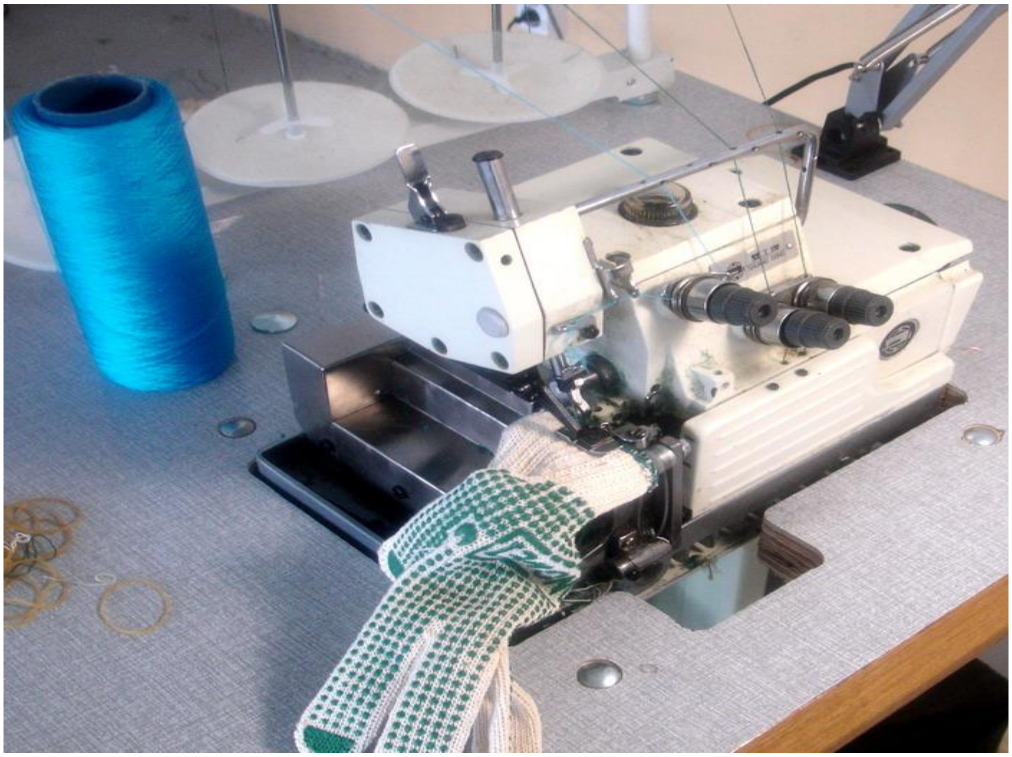

Fig- Gloves over locking machine

It is intended to sewing edges of glove's cuff with a polyester (polypropylene) string of the necessary color and density.

1.3.3. Packing of Gloves

Packing of gloves is done by the electronic packing machine. This equipment opens when ready for inputting the gloves, and it is on its level when ready for one dozen packing. The electronic system controls the whole process. This machine is essential equipment for every glove producer.

1.4 Performance of gloves

Glove performance and pass/fail criteria are included for the following hazardous exposures:

• Mechanical protection – cut resistance, puncture resistance, abrasion resistance
• Chemical protection – chemical permeation resistance and chemical degradation resistance
• Detection of holes
• Heat and flame protection – ignition resistance and burning behavior, heat degradation resistance, conductive heat resistance
• Dexterity

The new standard also includes a recommended hand protection selection procedure, and reference information on special considerations such as biological protection, extreme temperature applications, clean room applications, hazardous materials response applications, electrical protection and radiation hazards. A section on human factors describes how fit, function and comfort are incorporated into selection.

At some point in the glove selection process, users may be faced with a decision among different glove materials. When it comes to glove materials, some users may be sensitive to the proteins found in latex – an issue that has prompted the glove industry to find alternatives in materials such as vinyl nitrile and neoprene. Occasionally, users may experience glove-associated irritation that has nothing to do with an allergic reaction. Suggested tips for alleviating such symptoms include:

• Wearing a larger glove to increase air circulation until the hands heal

• Changing gloves more frequently to allow air to get to the hands if gloves are worn for long periods

• Wearing powder-free gloves

• Considering anti-inflammatory creams. But avoid petroleum-based creams while wearing gloves as they may compromise glove barrier integrity

• Choosing gloves low in residual chemicals

• Considering the use of glove liners made of cotton, nylon or other materials and replacing the liners every time gloves are changed

Cleaning/Maintenance

Both new and used gloves should be thoroughly inspected before wearing to ensure no damage is present. After each use, where reuse is intended, contaminated gloves should be cleaned. All gloves should be hand-washed and air-dried.

1.5 Mechanical properties of stainless steels

The mechanical properties of stainless steels are almost always requirements of the product specifications used to purchase the product. For flat rolled products the properties usually specified are tensile strength, yield stress (or proof stress), elongation and Brinell or Rockwell hardness. Bar, tube, pipe, fittings etc. also usually require at least tensile strength and yield stress. These properties give a guarantee that the material in question has been correctly produced, and are also used by engineers to calculate the working loads or pressures that the product can safely carry in service.

Typical Properties

Typical mechanical properties of annealed materials are as in the graph of following figure. The yield stress (usually measured as the 0.2% proof stress) is particularly increased by even quite minor amounts of cold work.

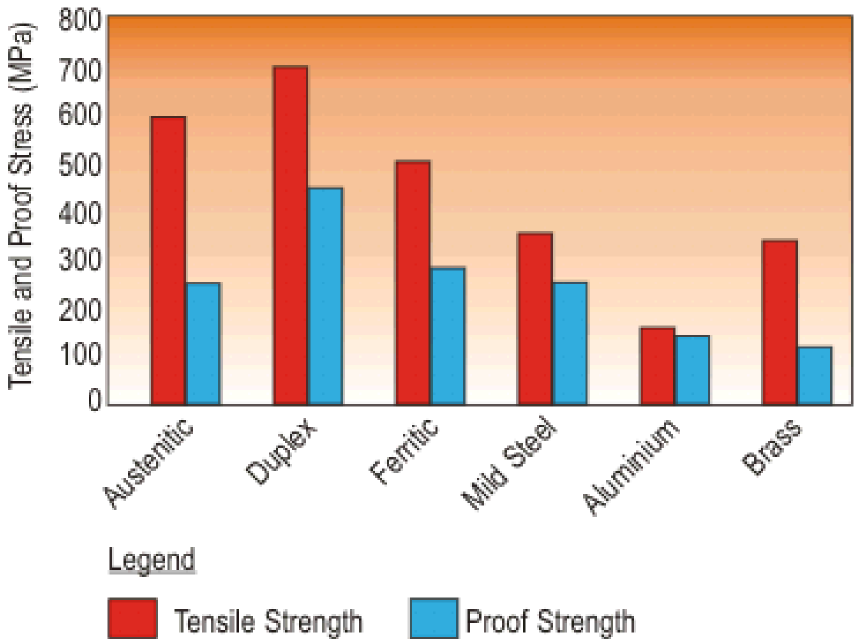

Figure- Typical Tensile Properties of Annealed Materials

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Yield Strength

An unusual feature of annealed austenitic stainless steels is that the yield strength is a very low proportion of the tensile strength, typically only 40-45%. The comparable figure for mild steel is about 65-70%. As engineering design calculations are frequently made on yield criterion the low yield strength of austenitic stainless steels may well mean that their design load cannot be higher than that of mild steel, despite the tensile strength being substantially higher.

Ductility

The other mechanical property of note is the ductility, usually measured by % elongation during a tensile test. This shows the amount of deformation a piece of metal will withstand before it fractures. Austenitic stainless steels have exceptionally high elongations, usually about 60-70% for annealed products, as shown in following figure. It is the combination of high work hardening rate and high elongation that permits the severe fabrication operations which are routinely carried out, such as deep drawing of kitchen sinks and laundry troughs.

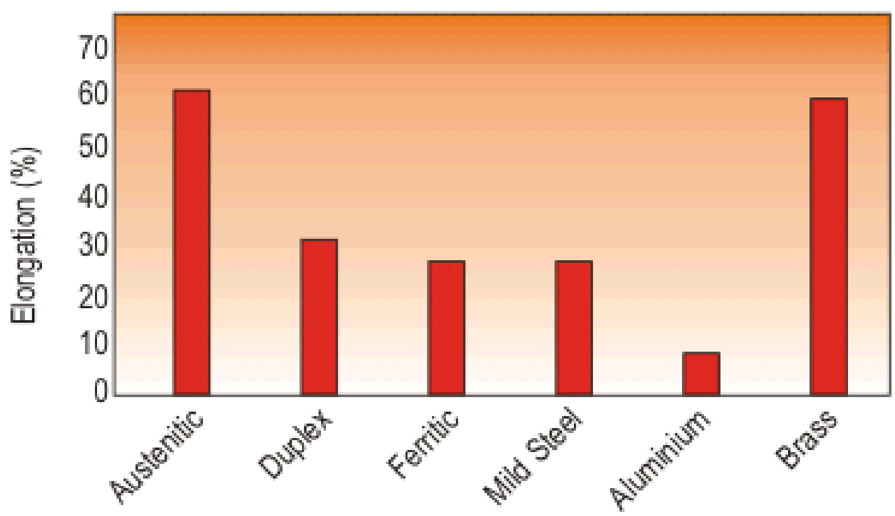

Figure Typical elongations of annealed materials

Hardness

Hardness (measured by Brinell, Rockwell or Vickers machines) is another value for the strength of a material. Hardness is usually defined as resistance to penetration, so these test machines measure the depth to which a very hard indenter is forced into a material under the action of a known force. Each machine has a different shaped indenter and a different force application system, so conversion between hardness scales is not generally very accurate. Although conversion tables have been produced these conversions are only approximate, and should not be used to determine conformance to standards.

It is also sometimes convenient to do a hardness test and then convert the result to tensile strength. Although the conversions for carbon and low alloy steels are fairly reliable, those for stainless steels are much less so.

Mechanical Properties of Wire

The mechanical properties of the majority of the stainless steel wire products are generally sufficiently described by the tensile strength. These products require mechanical properties which are carefully chosen to enable the product to be fabricated into the finished component and also to withstand the loads which will be applied during service. Spring wire has the highest tensile strength of the wire generally manufactured; it must be suitable for coiling into tension or compression springs without breaking during forming. However, such high tensile strengths would be completely unsuitable for forming or weaving applications because the wire would break on forming. Weaving wires are supplied in a variety of tensile strengths carefully chosen so that the finished woven screen will have adequate strength to withstand the service loads, and yet soft enough to be crimped and to be formed into the screen satisfactorily. Mechanical properties of wire for fasteners are another example where a careful balance in mechanical properties is required. In this type of product the wire must be ductile enough to form a quite complex head but the wire must be hard enough so that the threads will not deform when the screw or bolt is assembled into the component. Good examples are roofing bolts, wood screws and self-tapping screws; to achieve the mechanical properties required for such components requires careful consideration of the composition of the steel so that the work hardening rate will be sufficiently high to form hard threads on thread rolling and yet not so high as to prevent the head from being formed.

1.6 General requirements and test methods of Protective gloves

This standard is designed to ensure that the gloves themselves do not cause harm to the wearer and are comfortable to wear. Tests and requirements include the pH and chrome VI content of leather plus water vapour transmission and absorption of materials. Also procedures to examine the sizing of the glove and its effect on finger dexterity are covered plus general requirements for the information to be supplied with and marked on the glove.

Length

The length of the glove is measured by suspending it from the middle finger with a graduated rule having a rounded tip designed to fit the tip of the finger. The glove is manipulated to remove any wrinkles or folds and the minimum length is recorded. EN 420 includes a list of minimum lengths for each glove size, however, gloves for special purpose are permitted to be below the minimum length but in such situations the manufacturer must demonstrate that they are fit for special purpose by a statement in the user instructions.

Sizing / Dexterity

Gloves are fitted on a hand of the size that they are intended to fit and comments are made regarding comfort and fit. The wearer will then try to pick up pins of varying size to provide an indication of dexterity. Five pins are defined of diameter from 5 mm to 11mm, clearly the smaller the diameter that can be picked up the greater the dexterity result.

pH Value

The determination of pH value of both leathers and textiles on a glove is required. This pH value shall be greater than 3.5 and less than 9.5. The test samples are taken from the palm of the glove, if other part of the glove contains different material, these materials shall be tested separately. A prepared test sample is extracted in water by mechanical shaking; the aqueous extract is then decanted and the pH value determined by a pH meter. An excessive amount of acid or alkali in a material has been linked to skin dermatitis and may indicate poor process control.

BS EN 388: 2003 Protective gloves against mechanical risks.

This is the most common European Standard for testing gloves to be used in general industrial applications. It is also referred to in many of the specialist glove standards, for activities such as welding and handling of chemicals. EN 388 was first published in 1994 and subsequently revised in 2003. It includes four main physical tests to assess the resistance of the gloves palm area to mild abrasion, cutting, tearing and puncture. The performance of the glove is graded in accordance with four or five performance levels. The end user is then able to select a glove with a performance level profile that suits a particular work activity. So for example, a glove could be performance level 4 for abrasion but level 1 for tearing (in European standards the higher the number, the greater the protection).

Abrasion

Samples are cut from the palm of a glove and rubbed against a 100 grit abrasive paper using a “Martindale” type abrasion machine. The number of cycles for the samples to hole is measured. Four performance levels are defined in EN 388 ranging from level 1 = holing > 100 cycles to Level 4 = holing > 8000 cycles.

Blade Cut

Samples are taken from the palm of a glove and the number of cycles to cut through the full thickness of the test sample by a circular rotating blade is recorded. Blade sharpness will vary and is assessed by using the cut test machine to cut through a standard reference fabric. The cut resistance of the glove is based on a relative index that compares the number of cycles to cut through the glove when compared with the standard fabric. Five performance levels are defined in EN 388 ranging from level 1 = Cut index > 1.2 to Level 5 = Cut index > 20.

Tear

“Trouser leg” type samples are taken from the palm of a glove and are torn apart using a standard tensile test machine. Four performance levels are defined in EN 388 ranging from level 1 = tear strength > 10 N to Level 4 = tear strength > 75 N.

Puncture

Samples are taken from the palm of a glove and the force required to penetrate the sample with a defined stylus using a tensile test machine is measured. Four performance levels are defined in EN 388 ranging from level 1 = Puncture force > 20 N to Level 4 = Puncture force > 150 N.

2. Materials and Methods

2.1 Materials

The stainless steel mono filament yarn of 60 micron diameter has been procured from NIMROD INTERNATIONAL New Delhi, who is the sole supplier of the above filament in India.

Steel Filament:

Test Parameters	Test Method	Test Results
Filament Denier	IS: 1315-1977	202.85 (26.2 Ne)
Filament diameter (microns)	IS: 744	59.8
Breaking force, grams RKM (gram/Tex) RKM CV%	IS: 1670-1998	254.6 11.32 3.10
Elongation at break (%) Elongation CV%	IS: 1670-1991	31.91 9.24
Initial Modulus, grams/tex	IS: 1670-1991	12.30

Cotton fiber:

Test Parameters	Test Method	Test Results
Type of Cotton	-	Shankar 6
Micronair	ASTM D - 1448	3.95
Fiber Length, mm	IS: 10014 (Pt. 2) 1981	29.5
Tenacity (gm/denier)	ASTM D - 3822	3.33
Elongation at break (%)	ASTM D - 3822	6.8
Moisture regain%	IS : 199	6.6

Polyester fiber:

Test Parameters	Test Method	Test Results
Fiber Denier CV% of Denier	ASTM D-1577	1.43 4.77
Breaking Strength, grams CV% of Strength	ASTM D-3822	8.79 5.77
Tenacity (gm/denier)	ASTM D-3822	6.17
Elongation at break (%) Elongation CV%	ASTM D-3822	23.02 24.76
Fiber Length, mm CV%	IS: 10014 (Pt.2) -1981	37.76 3.03
Crimp, Arc/cm	ASTM D-3937	4.66

Nylon Fiber:

Test Parameters	Test Method	Test Results
Fiber Denier CV% of Denier	ASTM D-1577	1.74 9.23
Breaking Strength, grams CV% of Strength	ASTM D-3822	11.46 25.60
Tenacity (gm/denier)	ASTM D-3822	6.61
Elongation at break (%) Elongation CV%	ASTM D-3822	48.09 25.12
Fiber Length, mm CV%	IS: 10014 (Pt.2) -1981	35.92 1.99
Crimp, Arc/cm	ASTM D-3937	1.78

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2.2 Methods

The preparatory process to develop slivers of nylon, polyester and cotton fibers (to be used as sheath for making composite metallic yarns at DREF-3 machine) is described here as under.

Blow Room:-

The main purpose of blow-room is opening and cleaning of the material being used. The material is passed through various machines in order to achieve proper opening and cleaning. In Blow-room, machines are selected as per the beating points required to process nylon, polyester and cotton fibers.

Card:-

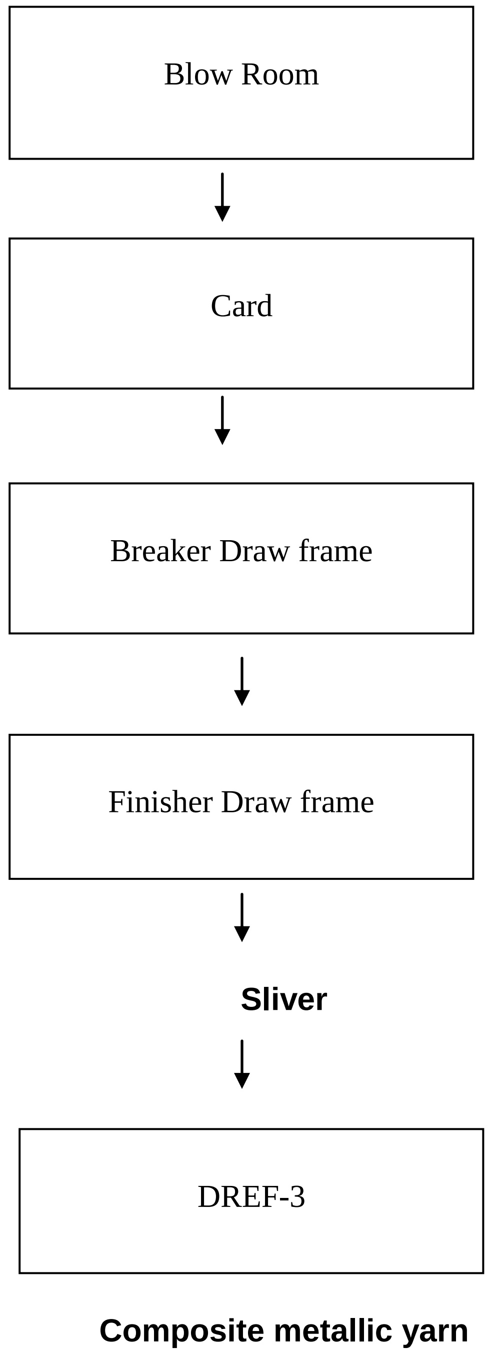
Carding is the heart of the entire spinning process and as such requires utmost care. 'To card well is to spin well' is a very widely used term by all those concerned with spinning technology. There have been remarkable changes in other areas of spinning, but so far as carding is concerned basic operation of the machine remained almost unchanged. The different speeds and settings are used to process nylon, polyester and cotton fibers and are summarized in process parameters

Breaker Draw frame:-

Draw frame is the process next to card. The main task of the draw frame is doubling and drafting. Doubling is done to improve evenness of the sliver.
Drafting is done to make the fibers parallel to each other. To obtain an optimal value for strength in the yarn characteristics, the fibers must be arranged parallel in the fiber strand.

Finisher Draw frame:-

The first passage in the draw frame is generally followed by a second passage. In the first passage, many slivers are fed together and at exit only one sliver is formed. The delivered sliver cans are again fed to second draw frame known as finisher draw frame. This is mainly done to overcome the irregularity and improve evenness in the sliver.



The yarns of 10^s were prepared using DREF-3 spinning system. In the beginning the trails were taken and process parameters were optimized and then bulk manufacturing of yarns were done DREF-3 machine at NITRA. These composite metallic yarns were converted to 2/10s count with the help of T.F.O machine. The plied (2/10s) composite yarns were used for making gloves and apron fabric. The sample codes, blend proportion and yarn counts are shown in the following table.

Samples, Materials and yarn counts

Product	**Sample code**	**Material**	**Fiber Proportion**	**Yarn count**
Industrial Apron	Sample No. 1	Steel/Nylon	30:70	$2/10^s$ Ne
	Sample No. 2	Steel/Polyester	30:70	$2/10^s$ Ne
Cut Resistant Gloves	Sample No. 3	Steel/Nylon	30:70	$2/10^s$ Ne
	Sample No. 4	Steel/Polyester	30:70	$2/10^s$ Ne
	Sample No. 5	Steel/cotton	30:70	$2/10^s$ Ne

2.2.1 Yarn Preparation

Composite metallic yarns of 10s count with 60 micron steel filament in core and nylon, polyester and cotton as sheath fiber on DREF -3 machine were prepared.

The DREF is composed of a rotating carding drum which opens the slivers into single fibers, and a specially designed inlet system being used for sliver retention. The fibers are then stripped from the carding drum by centrifugal force and carried into the nip of the two perforated spinning drums. The fibers are subsequently twisted by mechanical friction on the surface of the drums, which rotate in the same direction (S or Z). The process is assisted by air suction through the perforated drums.

Process Parameters:

Stage	Nylon	Polyester	Cotton
Blow-room			
Beater – I speed	600	600	650
Beater – II speed	780	780	880
Lap weight (gm/yard)	320	320	350
Card			
Licker-in speed (rpm)	660	660	660
Cylinder speed (rpm)	300	300	300
Delivery speed (mt/min)	80	80	80
Flats speed (mm/min)	150	150	140
Sliver hank	0.171	0.170	0.158
Breaker Draw-frame			
Roller Gauge (mm)	43/46	43/46	38/44
Top roller pressure	45 kg	45 kg	36 kg
Break Draft	1.30	1.30	1.16
Delivery speed mt/min	300	300	300
Sliver hank	0.211	0.210	0.205
Finisher Draw-frame			
Roller Gauge (mm)	43/46	43/46	38/44
Top roller pressure	45 kg	45 kg	36 kg
Break Draft	1.30	1.30	1.16
Delivery speed mt/min	250	250	250
Sliver hank	0.221	0.222	0.215
DREF-3			
Delivery Speed (mt/min)	100	100	90
Spinning drum speed	4500	4500	4400
T.F.O			
Spindle speed	6000	6000	5000
T.P.I	7	7	10

Note: Yarn samples of 2/10s Nylon/steel, polyester/steel and cotton/steel are enclosed as Annex-I

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2.2.2 Selection of Glove knitting machine

A good quality glove knitting machine was required for the development of cut resistant protective textiles using composite metallic yarn.

Trials have been taken on Chinese as well as Japanese glove knitting machines using composite metallic yarn and found that Japanese machine produced better quality of gloves. The extensive market survey also reveals that Japanese machines are better in technology & durability, offer higher productivity & good product quality as compare to Chinese and other brand machines.

The Shima Seiki, Japan developed the world's first automated glove knitting machine and since then it has been the forerunner of the glove knitting technology. The Shima Seiki machines are not only better in quality and consistency of knitting, but also metallurgy wise far superior than any other brands. That is the reason why the manufacturers who are making gloves with specialized cut resistant yarn, opt for Shima Sheiki machines only, because while running such specialized yarn, the yarn does not break, but wearing of the machine parts is more than the machine running with normal yarn. The 7G & 5G SFG machines are suitable for running specialized yarns. Therefore Shima Seiki SFG 7G L/M automatic glove knitting machine has been procured for glove making in this project.

Knitted gloves construction parameters

	Nylon/SS	Polyester/SS	Cotton/SS
Yarn count	2/10s	2/10s	2/10s
Course per inch	11	11	11
Wales per inch	10	10	10
GSM	500	500	500

2.2.3 Knit Sequence of Gloves

The knitting process starts at the tip of little finger and proceeds sequentially to the ring finger. Once the four fingers are complete, the palm whose width being equal to four fingers is knit. This portion is called the 4-finger palm. Knitting of the thumb starts at its tip. Once the thumb is complete, the palm whose width being equal to the five fingers is knit. This portion is called the 5-finger palm. The rib whose width being same as the 5-finger palm is knit. Finally, the X knit part is formed. This part is again as wide as the 5-finger palm.

2.2.4 Fabric Preparation for apron

The fabric for industrial apron has been prepared using 2/10s composite metallic yarns of nylon & polyester in our pilot plant. The steel core filament present in the composite metallic yarn is difficult to cut using normal yarn cutters available with the normal looms. Therefore fabric for industrial apron was developed on sample loom using 24/4 reed and 38 pick density.

Fabric Construction parameters:

	Nylon/SS	Polyester/SS
Yarn count	2/10s	2/10s
Ends per inch	48	48
Picks per inch	36	36
GSM	400	400

2.2.5 Testing Methods

All the knitted gloves and woven fabrics were conditioned prior to testing and all the tests were carried out under standard atmospheric conditions.

2.2.5.1 Thread Density

This is expressed as Ends/inch or Picks/inch depending upon the direction of thread. Longitudinal threads are known as Ends & transverse threads are known as Picks. These are counted with the help of magnification glass with ruler known as Pick Counter.

2.2.5.2 Count of Threads

Count of threads in a fabric can be determined by taking out 25-50 threads from a piece of 50cm x 50cm. These threads are weighted accurately on electronic balance and their length is determined after correcting the crimp and then the count is calculated. Thread density and count of threads affect the construction of the fabric & all other properties.

2.2.5.3 Weight of Fabric (GSM)

Weight of fabric is determined by weighing a fabric of any area say 25cm x 25cm & is generally expressed in terms of GSM (gram per square meter). Now a day's round cutters are also available to cut fabric of known area say 100 sq. cm.

2.2.5.4 Tensile Strength

Tensile strength is an important parameter as it is crucial for the life of the fabric. The breaking strength of a fabric refers to its resistance to tensile force and used for quality control as well as performance test. The tensile strength of a fabric should always be several times greater than the maximum stress likely to be encountered in use, because during the life cycle of most textile articles, strength of the fabric diminishes by the rubbing and chemical action. Tensile strength of fabric is determined on the Tensile strength tester.

Normally 4-5 strips in warp and weft wise direction are taken from the sample in such a way that most of the threads are covered. Then these strips are tested & results are expressed as average value in kg or **Newton.**

Cut strip method: The strip of fabric is cut exactly 2.0 inch wide. The test length should be 8 inch between the jaws so enough extra length must be allowed for gripping in the jaws. The specimen will be mounted centrally, securely gripped along the full width to prevent slipping and the jaws aligned and parallel so that the load is applied uniformly across the full specimen width. This method is used only for coated or heavy sized fabrics where reveling of threads is very difficult.

2.2.5.5 Tear Strength

Tear strength of fabric shows resistance to tearing force. For all flat sheet like materials such as fabric, plastic films and paper, the breaking strength of the material in tension is far greater than its tear resistance. It is difficult to induce a tear in any of these materials but the tear can be propagated at a relatively low load.
"Trouser leg" type samples are taken from the palm of a glove and are torn apart using a standard tensile test machine. Four performance levels are defined in EN 388 ranging from level 1 = tear strength > 10 N to Level 4 = tear strength > 75 N.

EN 388:2003 Tear Resistance Levels

Level 1	**Level 2**	**Level 3**	**Level 4**	**Level 5**
+10 N	+25 N	+50 N	+70 N	+100 N

2.2.5.6 Abrasion Resistance

Samples are cut from the palm of a glove and rubbed against a 100 grit abrasive paper using a "Martindale" type abrasion machine. The number of cycles for the samples to hole is measured. Four performance levels are defined in EN 388 ranging from level 1 = holing > 100 cycles to Level 4 = holing > 8000 cycles.

EN 388:2003 Abrasion Resistance Levels

Level 0	Level 1	Level 2	Level 3	Level 4	Level 5
0-99 Cycles	100 -499 Cycles	500 - 999 Cycles	1000 -2999 Cycles	3000 -9999 Cycles	10000- 19999 cycles

2.2.5.7 Pilling Grade

The ICI pilling tester was used for determining the pilling tendency of all the four knitted fabric samples. Tests were conducted as per the standard method IS: 10971-1984. The average of five tests was taken.

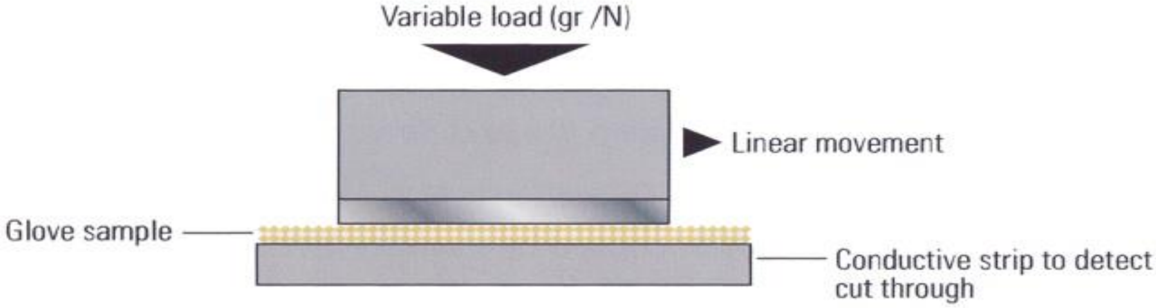
2.2.5.8 Air Permeability

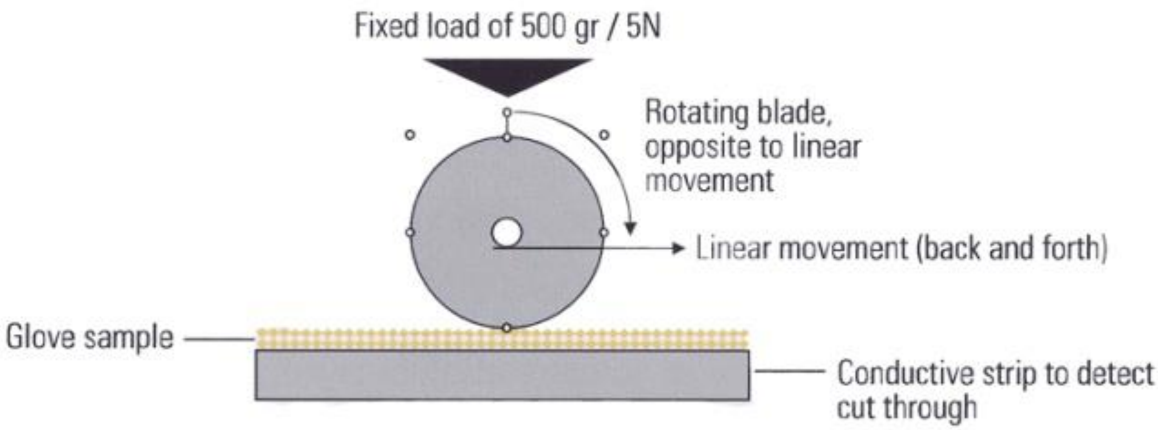
Air permeability of woven fabric samples was measured in a WIRA air permeability tester as per IS: 11056-1984 standard method. For each fabric sample average of twenty tests were taken. Air permeability was measured in terms of the measurement of the rate of flow of air through a given area of fabric by a given pressure drop across the fabric.

2.2.5.9 Blade Cut resistance

There are presently 3 different methods used to determine cut resistance: ASTM F1790 (the standard for the U.S.), ISO 13997 (The international standard) and EN 388 (the European Standard).

The ASTM F1790 and the ISO 13997 test methods use the CPP and TDM test method which consists of a straight blade that is slid along the length of a sample with three different weights. The sample is cut five times and the data is used to determine the required load needed to cut through a sample at a reference distance of 20 mm (0.8”). The EN 388 test method uses the Couptest which consists of a circular blade with a fixed load that is moved back and forth across the fabric to determine how long it takes to cut through. Again, 5 cuts are used to determine the cut index.





ANSI/ ISEA 105-2005 Mechanical Ratings:

ISO 13997:1999 Blade Cut Resistance Levels

Level 1 +1.2 N	**Level 2** +2.5 N	**Level 3** +5.0 N	**Level 4** +11.0 N	**Level 5** +22.0 N

ASTM F-1790 Blade Cut Resistance Levels

Level 0 0-199 grams force	**Level 1** 200-499 grams force	**Level 2** 500-999 grams force	**Level 3** 1000-1499 grams force	**Level 4** 1500-3499 grams force	**Level 5** above 3500 grams force

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2.2.5.10 Puncture resistance

Samples are taken from the palm of a glove and the force required to penetrate the sample with a defined stylus using a tensile test machine is measured. Four performance levels are defined in EN 388 ranging from level 1 = Puncture force > 20 N to Level 4 = Puncture force > 150 N.

Puncture Resistance (Newton)

Level 0	**Level 1**	**Level 2**	**Level 3**	**Level 4**	**Level 5**
0-9	10 -19	20 - 59	60 - 99	100 -149	Above 150

While it is certainly acceptable to use this rating (rather than using an absolute value) it remains a pretty relative measurement because of the range involved. For example a glove that gets a rating of 999 is rated as a level 2. A glove that is rated at 500 is also rated as a level 2. A glove that is rated at 1001 is rated as a Level 3 and yet the difference between the first two gloves is substantially larger than the difference between the last two.