PROTECTIVE GLOVES AGAINST MECHANICAL HAZARD

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Abstract
Using gloves as protection solution is the most efficient way to reduce accidents at workplace. Protecting hands is very important because in most of activities these are often exposed to injuries. Optimal level of protection is ensured by the appropriate type of glove, which should be selected according to the type of activity, objects and environmental conditions. To complete the protective gloves actions, one must consider the requirements regarding the comfort and flexibility to ensure work dexterity.
The paper presents an overview of the gloves that provide protection against mechanical hazard. Raw materials used for their manufacture, field of applications and the conditions to be met according to the risk encountered, are briefly presented. A study regarding the technical solutions of producing knitted gloves on various knitting machines is completing the paper, in order to outline the existing technologies for gloves production.
The second part deals with research of the technical potential offered by the regular two needle bed electronic flat knitting machine, CMS 530 E 6.2, Stoll, Germany, for producing knitted gloves. The research is seeking innovative solutions for glove fingers, connection between fingers, glove border, thumb position, with the purpose of developing protective knitted gloves in one low cost manufacturing stage.
Key words: protective gloves, knitted gloves, electronic machines, mechanical hazard.

1. The importance of the hand

The hand is the most complex and common used anatomical part of the body. It plays an important role in human life, it is an ultimate toll capable of doing a range of tasks from everyday communication (shake hands to say hello, speech in sign language when medical problems occurs, clap the hand to show appreciation) to simply manipulation of things (grasping a large object, picking up an object, writing with pen, turning the page, carrying things, keyboard tasting), as well as a weapon or an eating utensil. [1]
The skin of the hand is unique, on the dorsal part of the hand the skin is thin, flexible and more vulnerable to traumas. In the palm the skin is thicker, tough and more durable, it has a lot of lines spread in the palm and fingers. The individual blueprints are mapped out in those lines that are situated on the fingertips. The sense of touch is associated with hands. The palm has a thousand of nerves endings per square inch and most of them are situated in the fingertips though which the information of heat, cold, pain or vibration is detected within microseconds and sends it to the brain as a feedback. [2], [3].
Injuries caused to the hand like burns and cuts can do permanent damage to the nerves or skin, leading to loss of sensitivity, or in worst cases can lead to the loss of the hand. These damages affect not only the accuracy of touch but also dexterity, capacity of gripping and all others activities that are made with hands.

2. Types of protective glove

In daily activities hands are subject to repeated threats of injuries dependent on the workplace risks. The protection method that is used when the danger can't be eliminated trough engineering solutions (equipping machines with protection systems) is trough adequate protection equipment.
Gloves are the final physical barrier between hazard and skin and they must be chosen with great precision according to the risks the workplace and individual tasks involve. The gloves

are used when the hands are exposed to hazards like: chemical skin absorption, severe cuts or scratches, abrasions, punctures, chemical burns, extreme temperature, vibration, impacts, biologic contamination, electrical charges.
There are no gloves that provide simultaneous protection for all types of existing hazards. The variety of existing gloves depends on the type of protection they must provide. Different types of materials can be used to produce gloves, such as leather, rubber or plastic, cotton, synthetic fibers or combination thereof, see Table 1 [4]

Table 1 The types of gloves providing different protections

Type of gloves	Level of Protection
Metal Mesh	Protection to cuts from sharp objects.
Leather	Protects against rough objects, sparks, blows, chips and moderate heat.
Aluminized	Provides reflection and insulating protection against heat.
Cotton fabric	Protects against dirt, splinters and abrasions. Helps to grip slippery objects.
Aramid fibers	Protect against cold and heat, are cut-and abrasive-resistant.
Coated fabric	Slip-resistant qualities, used to handling and wire bricks. Are made from cotton flannel with napping on one side.
Rubber, Neoprene, Vinyl, Fluorocarbon, Butyl, PVC	Protects from chemicals or impair grip and dexterity.

The performance of protective gloves depends on a various number of factors such as: the type of glove material, manufacturing process, material thickness, design and size. All types of protective gloves must meet the standards that are set out in EU directives. They must be approved and labeled with CE marks, the symbol of European Conformation.
The EU Personal Protective Equipment Directive 89/686/ EEC divides glove into three categories by the level of risk:

Category 1 Gloves of "Simple" design

Such gloves are suitable for low risk activities: house cleaning, gardening and all other activities that imply easy work.

Category 2 Gloves of "Intermediate" design

These types of gloves have a design more complex than those of Class 1 and are designed to protect hands for intermediate risk activities that requires good cut, puncture and abrasion performance. The gloves should be tested and certified according to European Commission standard requirements.

Category 3 Gloves of "Complex" design

The gloves pertaining to this category are designed to protect against high hazards which may cause death or irreversible harm. This type of glove provides only limited protection against chemical attack or ionizing radiation.

All the gloves must meet several requirements of protective equipment [5]:

a. to be appropriate for the risks involved, without leading themselves to any increased risk;
b. to comply with existing condition at work;
c. to take into account the ergonomic requirements and worker health;
d. to fit the wearer properly after any necessary adjustments.

The requirements of the protective gloves are given in standard EN420 *General Requirements for gloves*. The standard defines general requirements regarding ergonomics, design and construction, comfort and efficiency, cleaning, innocuousness, type of material, marking and information supplied by the manufacturer applicable to all protective gloves [6].
Protective gloves are used by workers from many industries to ensure an optimal level of protection against encountered risks. Knitted gloves are the most useful types of gloves for activities implying objects manipulation or light assembly activities. They have the following advantages over other types of gloves: better fit on the wearer's hand given by increased formability of knitted fabrics, one stage knitting process, and the possibility of using high performance yarns.
This types of gloves are knitted using cotton yarns for light manipulations, or high performance fibers (para-aramid synthetic fiber Kevlar, Twaron, ultra-high-molecular-weight polyethylene fiber Spectra or Dyneema) usually combined with nylon or glass fibers for a high level of protection against abrasion, cutting, high temperature, etc.
To offer a high range of protection some of gloves can be coated with PVC to offer abrasion and puncture resistance, and if the surface is dotted it improves the grip.

3. Glove knitting techniques

A glove shape accurately suited to the hand contour is the main concern in designing a knitted glove. The method of 3-finger palm portion is used for a more natural fit on the hand and it comprises the following stages: (1) first is knitted the upper palm portion that includes the first three fingers - from the index to the ringer; (2) those three fingers are connected by knitting a number of rows separately from the rest of the palm, (3) the little finger is knitted the last and placed lower than other three providing a better fit and independent movement for a more comfortable glove. (Patent No.: US 2009/0211305 A1, Inventor: Eric Thompson) [7].
To increase comfort and for maximum flexibility and dexterity Ansell Limited has designed an ergonomically knitted glove improved in the flexural area of the hand by using open stitches giving the glove a better ventilation, a greater breathability and a higher comfort. The glove has different stitch densities by using Stitch Density Control that enhances glove stretch at the knuckle level and improve the comfort in various parts of the hand [8].
Several types of yarn with different proprieties (thermoplastic yarns, elastomers, metals) can be used to enhance the protection and comfort level of the glove. "Composites" gloves made of high performance yarns for critical risk areas and fabrics with low weight for the rest provide optimum protection in areas of high risk without limiting tactile sensitivity in the other areas. (US Pat. No. 6.155.084, Andrews et al.) [9].
Knitted gloves are usually obtained on specialized knitting machines. Such machines can produce gloves in one or two phase-processes. The two phase technology produces mittens without thumb, while by one phase technology the 5 fingers glove is produced automatically, with different thumb's position [10].
Usually the component parts of the glove are produced starting with the little finger, ringer, middle and index finger, continuing with the palm part, the thumb finger, the palm part and finishing with the border.
The five finger gloves are usually produced on specialized knitting machines, equipped with special devices for: automatic start of each tubular finger, connection between fingers, in order to avoid holes, insertion of an elastic yarn in the border structure, jacquard patterning for the glove palm area, narrowing edges of the tubular palm fabric. These machines are equipped with holding bar which holds 2 stitches from the previously knitted finger so when knitting the next finger they are already joined.

The regular knitting machines can produce knitted gloves as well as the specialized knitted machine. Because these are not equipped with special devices like common glove knitting machines other technical methods can be used to produce them. The connection between fingers can be made by crosslinking the loops from each finger edges, considering that the fingers are knitted side by side with no free needles at the edges. The technical solution implies knitting a tubular row and uses the split technique for knitting and transfer. For that the system must be equipped with a split cam to produce the crosslinking effect. The palm section is fashioned at both edges by successive narrowing of the tubular knitted fabric [11].

4. Experimental part

Gloves can be made on special knitted machine as well on regular flat knitting machine. The differences between those two stains in possibility of joining the fingers, number of yarn feeders used, devices used for automatic start of each tubular finger, elastic insertion device used in the border structure.

The paper presents technical solution to produce “composite” gloves on a regular flat knitting machine CMS 530, E6.2, Stoll, Germany. These gloves present different knitted areas, like pads spread on the glove according to the zones that must protect the hand from a specific hazard.

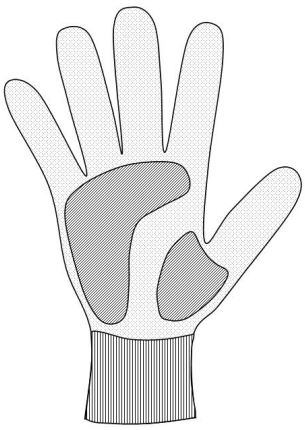


Figure 1 Glove with padded areas for abrasion resistance

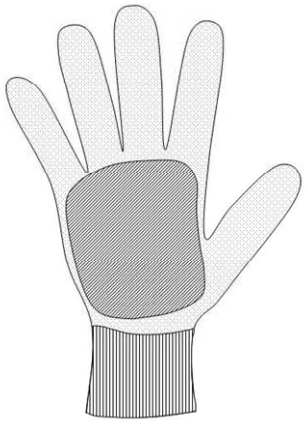


Figure 2 Glove with center protective area

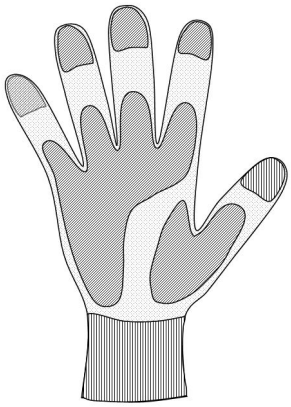


Figure 3 Glove with cut-resistance areas

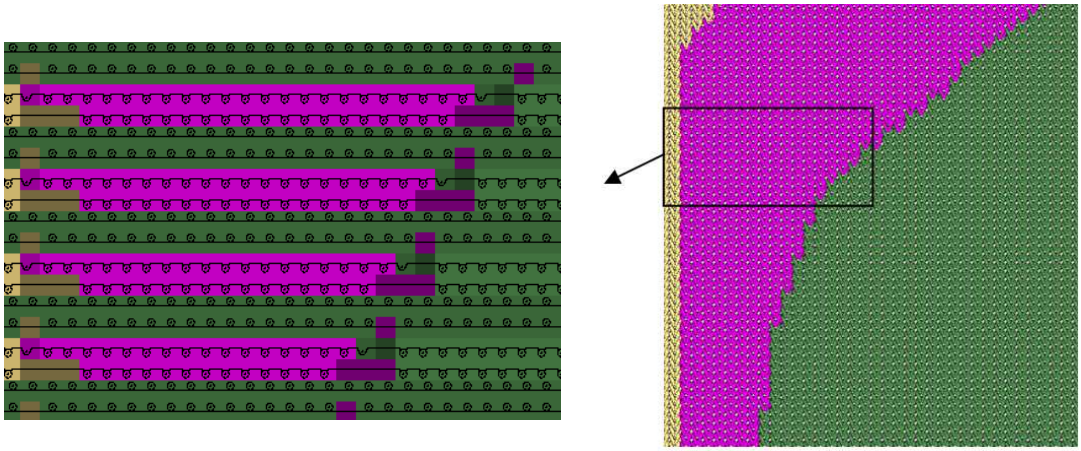
Knitted pads are like separated pieces fitted together like a puzzle by using continuous, one-step knitting process. Knitting machines used to make this type of gloves must be equipped with a large number of yarn feeders, one yarn feeder for each separated knitted section.

These types of gloves can be produced based on intarsia knitting technique. With this technique it is possible to create patterns with multiple colors fields. In this case colored field are replace by yarns with different proprieties.

The combination of used yarns is made based on the particular activities application in order to provide optimum protection against the threat of injuries that are most occurred. The expensive heavyweight yarns are place only on areas where greatest threat of injury is present, using in the rest of the glove a less expensive lightweight yarn. In this way the cost of the product and his weight is reduced considerably.

For example a cut- resistant glove can be made by combining a heavy weight fabric used in the area that must provide maximum cut resistance (like fingertips, over the length of finger, thumb stalls, palm area) with a lightweight fabric in the rest areas of the glove where tactile sensitivity is needed, see Fig.3. This type of glove is used in activities where the wearer is using sharp objects, cutting tolls, blades.

In activities like gardening, farming, or other activities that requires tactile sensitivity and abrasion resistance is needed a glove that has the central area (palm) made from a material that must have proprieties like good gripping or abrasive resistance. The rest of glove's areas are made from materials that offer a good dexterity, see Fig.1.
A technical solution of these composite gloves is offered by knitting all the different areas together in a seamless knitting process. Based on the intarsia technique different areas of the glove are joined together by loops between fields. These loops are created in the twisting zone of the colors to prevent the appearance of holes. The twist of the colors is performed only on the inside of the knitted fabric at the final product, see Fig. 4.



Knitting scheme of intarsia palm zone- Symbol view Fabric view of the pattern

Figure 4 Intarsia technique applied on the palm of the glove

Some gloves require double layer surfaces: an outside layer made of special yarns like cut-resistance to ensure protection against cuts and an inside layer made from yarns like cotton that assure comfort for the skin. The method used to obtain double layer surfaces have at the base knitted sandwich structure. The principle of sandwich fabrics stands in knitting individual layers on a two bed needle machines connected together by yarns or by using loops or stitches between layers, see Fig. 5.
On a certain zones of the gloves it can be used principle of sandwich structure to obtain double layer surface, see Fig.2. The sandwich area is knitted on the intarsia principle.

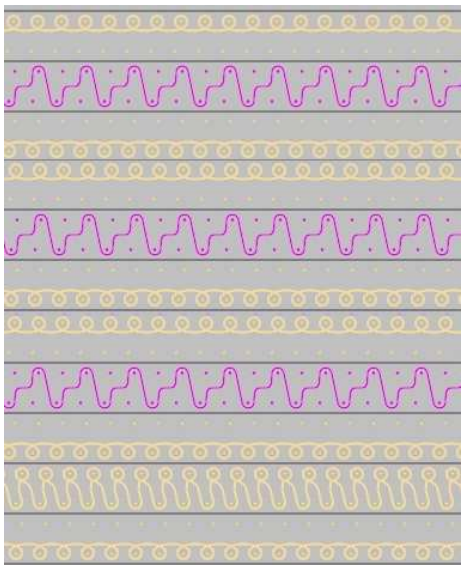


Figure 5 Knitting scheme of sandwich surface zone- Symbol view

5. Conclusions

Protective gloves are in generally designed to approximate the contour of the human hand and they include a finger zone (little, ring, middle and index finger), a glove body, a thumb zone, palm surface and is finished with a cuff. Preferably the entire glove is integrally formed using seamless knitting process.

Gloves designed to provide special protection (cut- resistant, puncture- resistant and thermal-resistant) can be made through manufacturing processes like dipping procedure, with either molds or supports, by punching and welding of plastic film sheets, weaving, sewing, knitting.

The yarns used are high performance yarns based on aramid polymer, high performance polyethylene or even steel yarns. Because this types of yarns are rigid and rough it is desired to avoid seams against to prevent any irritation cause to the wearer. The seamless construction of the knitting garment is the perfect solution on that.

Technical solution that is presented in this paper it can be performed on knitting machines that are equipped with two needle bed with the possibility that at least one of the two needle bed have the possibility of racking in order to perform the stitches transfer and more than one yarn carrier.

The “composite” gloves can provide protection without losing the freedom of movement, manual dexterity, tactile sensitive, comfort. These types of glove have some important advantages:

- assembling time of pieces is reduced by using continuous, one-step process of manufacturing;
- costs are reduced by diminution of inefficient use of heavy weight fabric;
- weight of the product is reduced;
- the quality and comfort of the product are increased by eliminating the sewing process used for joining the different type of surface.

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