Dynamic simulations to test the protective safety gloves: first results of a new methodological approach

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Abstract
Gloves are largely diffused as work tool in many activities. According to the Italian Law in force concerning health and safety at the workplace, the employer must endow of special PPE (Personal Protective Equipment) the workers (element not always effected) after the risk evaluation in which he has identified the characteristics of the ppe, according to the specifications of the work activities. On the market there are many brands of gloves with technical standards (EN 388 for protection against mechanical hazards and physical). However, there are still many accidents in which gloves didn't have the appropriate technical measures able to protect the worker. This search analyzes, through techniques for the evaluation planned for this study, the effectiveness of the gloves in real working conditions. From a methodological point of view, a protocol has been elaborated in order to test in the real sceneries the efficiency and the effectiveness of these PPE. First results show that the classes of resistance are not very often appraised by the employer and in this way the gloves used in agriculture don't always guarantee good performances in terms of effectiveness. Besides, the protocol defines a new methodic that could directly be gifted in the agricultural firm.

Keywords: PPE, choice, technical standards

Introduction
The use of equipments and tools in the agricultural sector expose the worker to high risks of crushing, perforation and abrasion of the hands, during the work activities. Insofar the first element that can protect and defend the worker is related to the use of specific and proper gloves. The cut performance of articles made of high performance materials is currently evaluated using several norm procedures (Rebouillat S., 2004).

The European EN388 Standard has been designed to assess the performance of a fabric or layers of fabric for their ability to withstand puncture, cuts, tearing and abrasions.

The test procedure includes a separate test for each of these qualities, and a performance level is awarded according to each test result. The test procedure includes a separate test for each of these properties, and a performance level is awarded according to each test result, for example a material with an abrasion resistance of between 100 and 500 cycles would be awarded level 1.
The minimum test results required to achieve the various performance levels are listed in the table number 1.

<table>
<thead>
<tr>
<th>TEST/PROPERTY</th>
<th>PERFORMANCE LEVEL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Abrasion Resistance-cycles</td>
<td>100</td>
</tr>
<tr>
<td>Blade Cut Resistance-cut index</td>
<td>1.2</td>
</tr>
<tr>
<td>Tear Resistance-Newtonss</td>
<td>10</td>
</tr>
<tr>
<td>Puncture Resistance-Newtonss</td>
<td>20</td>
</tr>
</tbody>
</table>

Table 1. Performance level EN388

When a protective glove has been approved for CE marking (Fig. 1) to the EN388 standard, these test levels are quoted as four numbers below the EN388 pictogram, the numbers are always shown in the order in which the tests are described. Please note the progression between the minimum results required to meet the increasing performance levels.

This means, for example, that the increase in test performance required to improve from blade cut index level 4 to index level 5 is eight times that needed to improve from level 1 to level 2. Also, where multiple layers of material are involved, the abrasion and tear resistance levels are derived from the most resistant of the individual layers, not the combination of layers.

It is important to note that blade cut resistance is the only test parameter where a performance level 5 is awarded. We will further discuss, whether even 5 levels are sufficient given the capabilities of new cut resistant technologies.

Cut tests have always had tremendous variability, and the ratings can give a false sense of comfort to the user, who might think that since it is a level 5, they are protected. Within the blade cut resistance level of 5, there is a wide range of performance.

We often hear safety professionals and glove manufactures speak of gloves being a “low 5” or a “high 5”.(figure 2).
So, it must mean that there is a need for additional stratification. Then, why don’t we add a level 6 and a level 7 so that will allow us to better stratify and qualify the level of protection.

A glove manufacturer can have a product that can withstand just over 2000 grams of cut resistance (most likely qualifying for level 5) and be classified in the same level as a glove that may take well over 5000 grams of cut resistance. It should be clear that cut levels are only a place to start looking, and are not the complete analysis for selecting PPE. The standardized tests can give us a directional indication of where to start looking, and then we can confirm that performance with real application tests in our workplace. Furthermore, real-world tests are needed because, for example, the way materials cut on a standard test machine is very different from the way those materials would cut if used in the palm of a glove that is immobilized under load. Perhaps an even more important performance area is that of puncture resistance.

A safety manager once summed it up, “Why are we considering the results of a test that essentially measures the puncture resistance of a roofing nail [the EN388 probe] when I am trying to protect employees from hypodermic needle threats?” Good question. The EN388 test for puncture resistance has three critical flaws as it relates to testing new material technology and new hazards. First, the probe is not adequate for testing the range of puncturing hazards that are prevalent in the market today. Second, the speed at which the probe moves is not representative of any application that you might find in the market (100mm per minute? Does anything move that slowly?). Third, it doesn’t allow for the fact that contact with the glove’s protective material can alter the probe and change future results.

So why the disconnect? It is not that the standards were not well developed. A lot of thought was put into the development of a reliable and consistent measurement. The problem lies in the lack of good alternative test probes that are consistently produced and the evolution of new technologies, products and materials that simply don’t test the same way that other materials test.

In order to define the appropriate PPE for his workers, the employer needs to know:

- how much weight must be applied on the cutting or puncturing force
- how fast is the moving and how high or low is the impact
- what are the knowledge about the weaknesses of the PPE

The market is changing rapidly. New materials are improving our ability to protect from threats that were previously elusive. There is certainly a need for new standards to help the measure of these threats, but first of all we need to be aware of what the current standard tests are actually measuring.
The aim of the present search is to test different typologies of safety gloves in real conditions (pruning yard) by using three different tools (pruning, electric and manual shears) in order to evaluate the validity of the products commercially available and to study possible solutions.

**Materials and methods**

From a methodological point of view, the survey has been carried between January 2011 and March 2012. The protocol required the use of the following equipments:

- **Pneumatic shears**

<table>
<thead>
<tr>
<th>Technical Information pneumatic model</th>
<th>working pressure</th>
<th>cutting capacity</th>
<th>air consumption</th>
<th>net weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>model SLY</td>
<td>08-ott</td>
<td>30</td>
<td>80</td>
<td>0,55</td>
</tr>
</tbody>
</table>

*Table 2. Technical data*

- **Electroportable pruning shears**

<table>
<thead>
<tr>
<th>model FELCO 820</th>
<th>Cutting capacity</th>
<th>Size</th>
<th>Net weight</th>
<th>Weight of the battery pack</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mm</td>
<td>mm</td>
<td>kg</td>
<td>kg</td>
</tr>
<tr>
<td></td>
<td>45</td>
<td>290</td>
<td>0,98</td>
<td>2-2,5</td>
</tr>
</tbody>
</table>

*Table 3. Technical data*

- **Manual pruning shears**

The gloves, classified according to the EN388 and second price elements (Table 4), were tested during the experimental period.

<table>
<thead>
<tr>
<th>Class</th>
<th>Level</th>
<th>Cost (Euro)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 economic class</td>
<td>low</td>
<td>&lt; 6</td>
</tr>
<tr>
<td>2 economic class</td>
<td>medium</td>
<td>6 price 12</td>
</tr>
<tr>
<td>3 economic class</td>
<td>high</td>
<td>&gt;12</td>
</tr>
</tbody>
</table>

*Table 4. Economic classes*

Every typology of glove has been submitted to the cut of the equipments. The effects of the cut are considered according to the impulse of a force and not as repeated cycles (from the
normative EN388); this force was constant for the pneumatic and the electroportable shears, while was variable for the manual ones.

To assess the damage, because of the impossibility to detect with load cells (invasive tests that lead to the destruction of the sensors) the fingers and the frame of a hand have been rebuilt by using biological and woody materials very similar to the morphological characteristics and resistance of the fingers of the hand.

Impulse I produced from time t1 to t2 is defined to be:

\[ I = \int_{t_1}^{t_2} F \, dt \]

For each test, the damage was classified according to three parameters:
1. the cut on the glove;
2. the damage on the finger’s soft tissue;
3. the damage on the bone.

<table>
<thead>
<tr>
<th>Glove</th>
<th>Soft tissues</th>
<th>Bones</th>
<th>Descriptor</th>
</tr>
</thead>
<tbody>
<tr>
<td>A0</td>
<td>B0</td>
<td>C0</td>
<td>Absence of damage</td>
</tr>
<tr>
<td>A1</td>
<td>B1</td>
<td>C1</td>
<td>Slight, insignificant, hardly discernible damage</td>
</tr>
<tr>
<td>A2</td>
<td>B2</td>
<td>C2</td>
<td>Significant harm by cutting, tearing or crushing</td>
</tr>
<tr>
<td>A3</td>
<td>B3</td>
<td>C3</td>
<td>Total shearing</td>
</tr>
</tbody>
</table>

Table 5. Damage evaluation

Results
The used method has provided ten repetitions for each test. Statistical analysis has not been performed because of the uniformity of the responses, with any variation.

The first graph (figure 3) shows that the responses of the gloves were very poor even with the use of the manual shears: the gloves also G1 and G2 (considered anti cutting), although there were no significant damage to the glove, show a total damage of the soft tissues and of the bone (Fig. 4).

The only positive outcome was related to sample N. G6, in which the soft tissues come significantly damaged, but the bones remain unchanged (Fig. 5).
Figure 3. Test n.1

Figure 4. Damage sample for G2

Figure 5. Damage sample for G6
In the use of pneumatic shears, see Test n.2, the result has identified only one element of strength, always referred to the glove G6, nevertheless with significant damage to soft tissues and bones.

The last test (Fig. 7) has in fact shown as electric shears are the most dangerous of all. In fact, although they are progressive, and then the operator can intervene on the block of the blade, can cause an impact of greater importance, hardly stoppable also with tissue cutting.

Conclusions
The research has shown that the gloves commercially available are currently not eligible.
These products are in fact designed to be used in static and standardized areas, in which the risk factors are due to known forces and accidental elements with a single effect (only cut, only abrasion or perforation).
Even using gloves with high performance, the result is the same, causing the total amputation of the fingers of the worker. The research, although has shown some positive results on the use of steel mesh gloves, doesn’t propose such solution as applicable in the agricultural sector, because of they are very heavy and with very little skill.
Moreover, because of their characteristic, they can easily become entangled in the branches and vegetation. In the future, we must change the current standards for identifying a
glove for the agricultural context: only building gloves that consider impulses and energies we can obtain better PPE.

References

