Contemporary Engineering Sciences, Vol. 8, 2015, no. 26, 1215 - 1227
HIKARI Ltd, www.m-hikari.com
http://dx.doi.org/10.12988/ces.2015.56179

New Personal Protective Equipment for Cutting and Shearing: Finger-safe

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Abstract

The personal protective equipment used in agriculture does not include specific devices and due to this fact they are not able to provide a suitable degree of protection of the operator. In particular, the hand is the part of the body that is more prone to serious injury (e.g. amputation). The aim of this study was to test new safety principals for reducing the risk of cutting. We performed 10 types of different tests that led us to the identification of gloves resistant to mechanical action as well as to cutting. The prototype has demonstrated a high protective efficiency against tools such as pneumatic or manual scissors. In conclusion, the study recommends the use of gloves with elements which absorb and dissipate energy and not just simple cut resistant gloves.

Keywords: Gloves, safety, personal protective equipment

1 Introduction

Eurostat data from 2008 indicate that the agriculture and construction areas record a high number of injury cases. The data showed that construction workers are involved 3-4 times more than other workers in work-related injuries.

The agricultural sector is characterized by the heterogeneity of possible products and by the variability of techniques that can be adopted to achieve the same product.

There are also present companies that pursue more productive working areas for which is necessary to schedule all needed tasks, which consequently implies that at certain times of the year the companies assume occasional operators, not trained on the risks and more prone to accidents. In agriculture we can identify the following problems:

- general high age of the operators;
- extreme variability of operating and environmental conditions;
- overlap between working and living environment;
- poor training of employed staff.

The knowledge is the first security parameter and by analyzing the working environment increases the knowledge and consequently the perception of risks. In a working environment characterized by the presence of so many variables, security management becomes difficult and the level of attention for "specific and daily behavior" must be always high. The extent of injuries in agriculture has led the European Commission to declare agriculture as a high risk area based on the frequency and severity of accidents. Farm operators usually do not carry out exclusive tasks but are involved in several different activities, which expose them to multiple risk factors in the working environment as well as in work organization (National Safety Council, 1996). The classification of possible types of accidents and occupational diseases which can affect agricultural workers includes diseases related to the working environment, to working materials (crops, fertilizers, animals, pesticides) and finally related to working tools. Among the above mentioned accidents or diseases, it is important to notice the damage caused by atmospheric factors (e.g. sun stroke, shock, respiratory, rheumatologic and pulmonary infectious and parasitic diseases). Among the pathologies related to used working materials should be highlighted traumatic injuries and acute and chronic diseases derived from contact with animals, use of pesticides, natural and synthetic fertilizers (e.g.. broncho-pulmonary disorders due to dust, pesticides and fertilizers, respiratory allergies to hay or excrements and dermo-epidermal derivatives of animals or fungi, contact dermatitis with chemicals of plants or animals, infectious and parasitic diseases). Diseases related to the use of agricultural tools are mainly traumatic injuries of various types and entities such as puncture wounds and cutting, laceration and contusions caused by tools such as shovels, hoes or pitchforks, bone injuries from falling, trauma by shock, strain injuries, amputations and traumatic injuries from mechanical instruments or vibrational damage, ear damage, arthropathies for micro-trauma and poisoning by exhaust gases. Muscle and joint disorders as well as posture deformations are determined by un-natural or forced working position. Based on the occurrence of accidents, agriculture is characterized by having a high number of risks related to cutting and shearing activities. The main objective of this work was the study possible injuries and development of suitable protection systems related to mechanical and cutting risks during agricultural, agro-industrial and forestry activities. In specific, the study intends to:

- analyze the performance levels of gloves used in agriculture;
- define a methodology for the definition of dynamic tests;
- build a prototype capable of resisting to specific stressors present in agriculture.

2 Materials and methods

The methodology was divided into two specific phases:

1. discussion on the forces developed by a contact between hand and glove; specifically examining the forces exerted by a contact between a sharp agent – PPE (Personal Protective Equipment) - operator's hand;

2. test trials and evaluation of the glove resistance and creation of new personal protective equipment.

In order to define the forces during gloves impact with a glass pane we simulated three possible scenarios which may occur throughout the production activities:

- fall of the glass pane near the operator (less than 0.50 m and still less than the length of the operator’s forearm; operator is likely to be crushed by the pane);
- fall of the glass pane at a distance greater than 0.50 m from the operator (like an accident in which the operator can grab the pane but is not crushed by the pane);
- fall distance greater than the height of the glass pane (greater than 1.00 m, the operator tries to grab the glass pane during falling to prevent its breakage).

A group of 10 individuals of heterogeneous age, sex and physical characteristics was selected and each individual grabbed a chipboard panel comparable to a glass pane positioned at the height of 0.75 m dimensions. Each individual performed three tests at selected distance.

By connecting the palm of the hand to a dynamometer we could measure the energy at the moment of contact between the hand and glass pane. The subsequent processing of the data allowed us to define three standard values (expressed in kN) for each simulated situations. The analyzed physical principle was the impulse; a vector unit measured in Newton per second which is defined in classical mechanics as the integral of a force over time.

$$\vec{I} := \int_{t_0}^{t_1} \vec{F} \mathrm{d}t \tag{1}$$

In the case of the application of a constant force over time, we have:

$$\vec{I} = \vec{F} \Delta t \tag{2}$$

In the case that is completely inelastic, the bodies after the collision remain in contact and can be considered as a single body and travel with the same speed different from the initial speed of the two bodies.

The law of conservation of momentum of the system:

$$P_t = \sum M \cdot v = cost \tag{3}$$

for total inelastic collisions, it is possible to write:

$$m_1 v_1 + m_2 v_2 = (m_1 + m_2) \cdot V \tag{4}$$

where $m_1 v_1$ e $m_2 v_2$ are the momentum before the collision of the first body mass m_1 and the second body mass m_2, while $(m_1 + m_2) \cdot V$ is the momentum of the entire system after the collision, when two bodies merge into a single body mass equal to the sum $m_1 + m_2$, V is obtainable from the expression (4) and represents the speed with which the two bodies move after the collision.

In this case two types of error should be considered:

- the hand is not a rigid body;
- some of the forces that act on the system were not taken into account (e.g. friction);
- the impact that creates a result should occur at an specific angle between the hand and sharp object (principle of the guillotine).

In order to scientifically prove the experiments, we simulated human fingers with materials of animal origin (soft tissue) and pieces of wood (simulation of bone structures).We have also respected anthropometric and dimensional characteristics of fingers of an average hand. In order to make the tests replicable in a standardized way it was decided to determine the characteristics of each used material (Table 1).

BRAND	PRIMO PREZZO
COMPOSITION	Chicken and turkey
WEIGHT	25 g
DIAMETER	2,0 cm

Table 1 – Characteristics of the animal material used during tests to simulate soft tissues

	BIC EVOLUTION*	KOH·I·NOOR*
CONSTITUTIVE MATERIAL	graphite wood-free (synthetic resin)	linden wood resins and knots -free
LENGTH	17,5 cm	
WEIGHT	70 g	

Table 2 – Characteristics of the material used during tests to simulate bone structures.

Figure 1 – Classification of the damage on fingers from left to right - scale of damage (1.2.3.4)

Figure 2 – Classification of the damage on fingers from left to right - scale of damage (1.2.3.4)

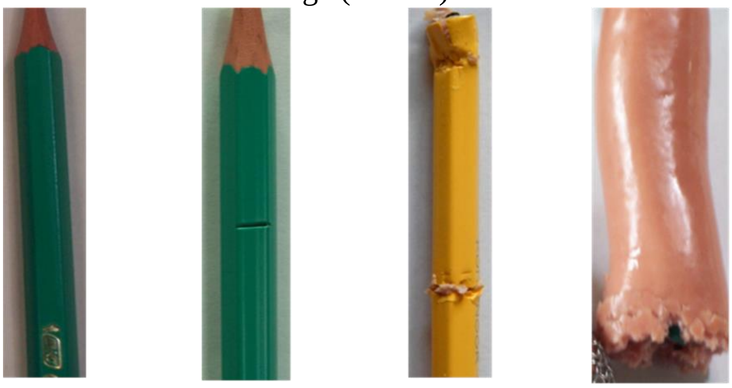


Figure 3 – Classification of the damage on the bone from left to right - scale of damage (1.2.3.4)

3 Results

In this type of experiments we have tested dissipators of our design with the ultimate goal to reach a solution that yields a PPE (Personal Protective Equipment) which ensures an appropriate degree of protection to the user. The scheme of the potential solution is shown in Figure 4.

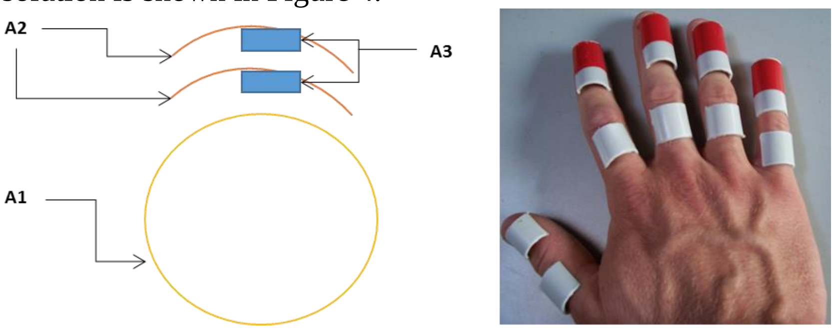


Figure 4 – Operational mode of the dissipator and areas protected by the dissipator for each phalanx: A1: Glove, A2: Plastic Elements, A3: Rubber Dissipator

DISSIPATOR	REPLICATES	PNEUMATIC SCISSORS	
		FINGER DAMAGE	BONE DAMAGE
PVC + PE	1	3	3
	2	3	3
	3	3	3
	4	3	3
	5	3	3
	6	3	3
	7	3	3
	8	3	3
	9	3	3
	10	3	3
	11	3	3
	12	3	3
	13	3	3
	14	3	3
	15	3	3

Table 4 – Cutting tests with pneumatic scissors.

All tests were carried out by the action of manual, pneumatic or electrical scissors and the type of sustained damage was considered.

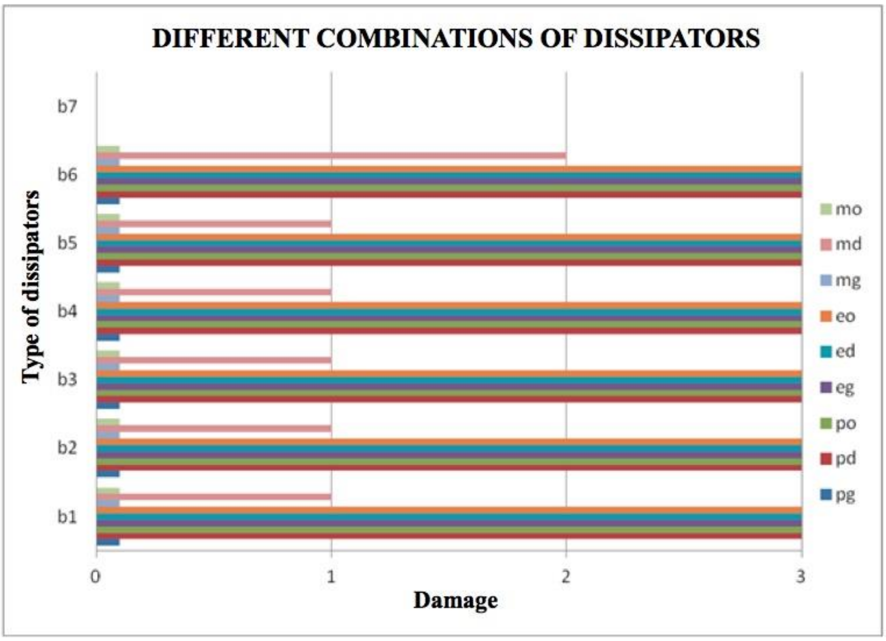
In order to validate the test, for each type of test were made replicates, in total about 7000 replicates of 10 test series (5 cutting and 5 crushing) (Table 3 and 4).

		TEST WITHOUT DISSIPATOR	TEST WITH DISSIPATOR	TEST WITHOUT GLOVE
CODE OF THE GLOVE	REPLICATE	DAMAGE	DAMAGE	DAMAGE
		/	/	3
A1	1	2	2	3
	2	2	2	3
	3	2	2	3
	4	2	2	3
	5	2	2	3

	6	2	2	3
	7	2	2	3
	8	2	2	3
	9	2	2	3
	10	2	2	3

Table 5 – Resistence to crushing with a weight of 2.0 kg

From Fig. 5 it is evident that only manual scissor cause a limited damage and affect only the soft tissue, while the pneumatic and electrical scissors cause serious damage which involves soft tissues and bone structures with consequent shearing. The type b7 of the dissipator was not taken into account, as though giving an adequate level of protection; it was too large and could become a discomfort factor as well as an impediment during normal activities. The objective of the test was to find a suitable solution which allows the simulator of the human anatomy to remain intact; therefore, the applicable solutions are B1 to B6 for manual and pneumatic scissors. In the case of electric scissors none of tested solutions was sufficiently efficient and complete cutting of the finger occurred. This finding can be explained on the basis of the operational principle of the scissors.



Legend	
pg	Damage of pneumatic scissors on gloves
pd	Damage of pneumatic scissors on fingers
po	Damage of pneumatic scissors on bones
eg	Damage of electric scissors on gloves
ed	Damage of electric scissors on fingers
eo	Damage of electric scissors on bones
mg	Damage of manual scissors on gloves
md	Damage of manual scissors on fingers
mo	Damage of manual scissors on bones

Legend	
b1	1 above
b2	2 above
b3	2 above + 1 below
b4	3 above + 2 below
b5	2 above + foam rubber
b6	2 above + foam rubber + 1 below + foam rubber
b7	2 above + foam rubber + 2 below + foam rubber

Figure 5 – Summary of data obtained with different types of gloves

4 Conclusions

Personal protective equipment used in various agricultural activities is not specified for single tasks and due to this issue it is not able to provide a suitable degree of protection of the operator. In fact, it can be stated that the damage reported in case of injury, with the use of personal protective equipment is quite comparable to the damage that would occur in the absence of any safety device. Based on the accident data it is clear that the hand is the limb with the highest number of accidents involving an anatomical loss.

The work aimed to propose an innovative and effective solution of the cutting-shearing problems occurring in agricultural processing. The developed solution is highly innovative because at the moment we do not have any similar devices on the market that effectively reduces the extent of the damage. This is implemented and functioning equipment, and in the case of accident we can pass from shearing of the limbs to lighter lacerations or perforation without involvement of the deep tissue layers. This means saving the overall anatomy resulting in a positive impact both economic and biological.

This solution is specifically identified for the agricultural sector and is easily applicable to all activities, it is tested to withstand the equipment used in pruning operations and also to provide protection even in the case of crushing.

The developed system can be applied directly on the dpi, or can be placed by the operator under the same PPE (Personal Protective Equipment). [27]

The real impact of this device can be defined by the reducing number of accidents involving hand-arm and by the reduction in the severity of injury cases. These effects will also impact on health level which is quantifiable with a reduction of days of absence from work and the type of non-permanent and less invasive injuries in case of accidents.[28]

From the economic point of view, the cost of the dissipator will not impact significantly the final cost of the dpi, as its production cost can be quantified in a few euro cents.

The prototype needs to be further engineered and implemented, considering the replacement of the plastic material with another more powerful such as carbon fiber, polycarbonate or other new composite materials.

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Received: March 30, 2015; Published: October 16, 2015