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G.D. TANASIEVICI[1], N. CIMPOEŞU[1], D.P. BURDUHOS NERGIS[1],
A.M. CAZAC[1*], O. RUSU[1], G. BĂDĂRĂU[1], C. BEJINARIU[1]

WEAR-CORROSION ANALYSIS OF STAINLESS STEEL NETS USED IN FOOD INDUSTRY

The present work aims to identify the types of stainless steels used in the food industry and implicitly in protective equipment in correlation with European and Romanian regulations and standards in order to align the equipment's used in Romania to European Union standards. The work is also a review of the studies related to the properties of stainless steels in correlation with the maintenance of protective functions against the risk factors that act on the human body. The limits of stainless steels in the design of individual protective equipment are identified so that they maintain their function as a physical obstacle between the danger and the performer, to protect the body depending on the directions on which the dangerous factor can act and to meet the ergonomic and condition maintenance requirements of health. A new and a used stainless steel net from Food Industry field were analyzed by wear and corrosion point of view. Scanning electron microscopy (SEM) was applied for determination of the stainless steel deformation degree in used net, the corrosion sites and wear stains. For corroded areas the compounds formed were identified based on energy dispersive spectroscopy (EDS) results.

Keywords: Stainless steel; protection net; SEM; EDS

1. Introduction

The notion of "personal protective equipment" was introduced in the specialized literature as a result of the appearance of equipment designed to be worn or held by workers to protect them against one or more risks that could endanger their safety and health at the site for work. From a legal point of view, the notion of "personal protective equipment" is regulated by a set of organic and specific laws that refer to the production and use of this equipment. Currently in Romania, the legislation on the production and use of personal protective equipment has been harmonized with European legislation and standards based on Regulation (EU) 2016/425 which establishes requirements for the design and manufacture of personal protective equipment [1,2]. As there are many risks of injury in gainful activities, collective and individual protection are considered paramount in ensuring the safety and health of workers. Thus, personal protective equipment is used to reduce workers' exposure to hazards as a barrier between them and the hazards of injury. Personal protective equipment can be classified according to the part of the body it protects. A first category includes various suits, lab coats, overalls, life jackets, safety harnesses and aprons that can cover the whole body or just the torso. Leg protection can be covered by trousers, gaiters or boots. Gloves and arm guards can be used to protect the arms and hands, while hoods and balaclava serve for the head. Other types of PPE besides protective clothing also include respirators, goggles, face shields, helmets and earmuffs (earmuffs) [3-5].

There is a category of personal protective equipment made entirely of metal materials, which brings to the attention of researchers a less studied assortment, namely those intended for the meat processing industry (aprons and metal gloves). Workers in the food industry are a category very exposed to the risk of injury, and for these reasons individual protective equipment for the hands, namely gloves with steel links, which provide protection that prevents or diminishes, plays an important role in ensuring protection the action of occupational injury and disease risk factors. Thus, it is already known that the performance of steel chain gloves for the food industry is influenced by the type of stainless steel used. These gloves must be resistant to wear, environmental factors under the conditions of use, as light as possible and must not adversely affect the health or safety of users [6-9].

David Caple in a 2000 report on the evaluation of cut resistant gloves in the South Australian meat industry, building on research carried out in the USA by Dupont (Blocker and Rivet, 1994) comparing the performance of glove materials of protec-

[1] TECHNICAL UNIVERSITY "GHEORGHE ASACHI" FROM IASI, FACULTY OF SCIENCE AND MATERIAL ENGINEERING, 41 DIMITRIE MANGERON BLVD, 700050. ROMANIA

* Corresponding author: alin-marian.cazac@academic.tuiasi.ro

tion have shown that cut resistance is directly correlated with increased weight of the glove material, research by Holmer (1994) who reported the detrimental effect on performance due to hand cooling and design, of Geng, Chen & Holmer (1997) who reported reduced hand dexterity when working in low temperature environments and Flemming, Jansen & Hasson (1997) who indicated that wearing a glove while holding a knife handle can increases physiological fatigue conclude that in South Australia meat worker injuries consisting of hand lacerations can be reduced by permanent wearing of protective gloves on both hands [4,10].

In this paper the authors perform an analysis on the main defects that appear on metallic gloves used in butcheries after two years of usage. The defects are caused by mechanical external forces contacts like butcher knives or bards, the high or low temperature alternation between the cold stores and kitchen temperatures.

2. Materials and methods

Three different types of metallic mesh used gloves were analyzed on areas with structural defects. The metallic gloves present defects after 2 years of usage and we establish parts of the causes. The metallic gloves were used in facilities like: Kosarom, Sellgros and M&R were after two years were replaced for different mechanical problems. The initial state of the glove and some examples of defects after 2 years of usage are presented in Fig. 1. The metallic rings analyzed in this paper were extracted from the damaged areas of the gloves were the holes appear, Fig. 1, and were the metallic net was destroyed by different causes.

The areas with defects of the metallic protection gloves were analyzed with optical macroscope, portable lcd macroscope, in order to establish the defects at a macro-scale, scanning electron microscope (SEM VegaTescan LMH II, SE detector, 30 kV power gun, 35.5 working distance) and for chemical composition insigths an Energy dispersive spectrometry detector (EDX) from Bruker using automatic and element list modes also Mapping and Point investigations. Scanning electron microscope was used in high vacuum at 27-35.5 mm working distance and 30 kV electron gun power supply. The SEM equipment enclosure was continuously purged with gaseous N for cleaning. The samples analyzed were extracted from the used gloves and the cut was realized outside the analysis area.

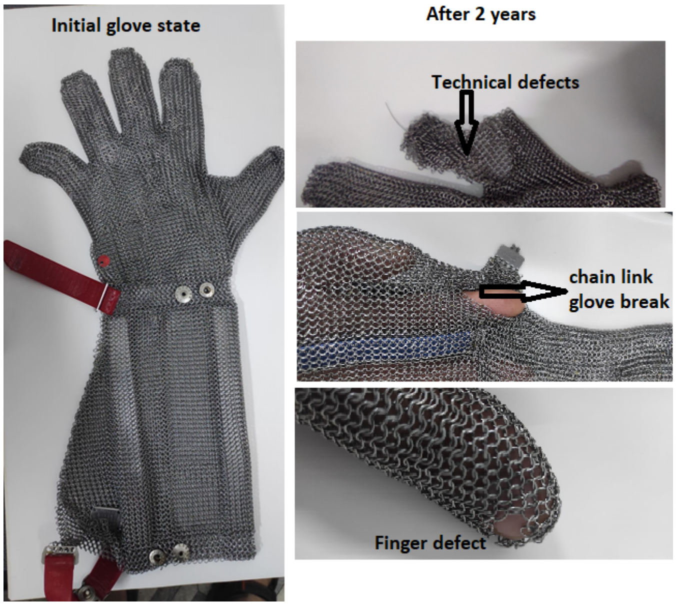


Fig. 1. Metallic protection glove for butchery as initial state and after 2 years of usage

3. Experimental results

Metallic rings with defects identified by optical macroscopy are presented in Fig. 2. The main problems identified are conected to local deformed areas, Fig. 2(a), oxidation and corroded zones, Fig. 2(b) and deformation of the rings because of the external forces. The steel mesh glove is widely worn by workers in the meat industry and not only, but due to the material from which it is made, it presents a number of inconveniences, namely: it interferes with the hand, it imposes a rigidity in the movement of the fingers, it maintains a temperature low on the fingers. Although research in this field has continued for the past 20 years, and the use of cut-resistant gloves in the food industry is a legal obligation, occupational accidents resulting in finger lacerations among workers are a persistent phenomenon [11,12].

Further research will be needed for the meat industry to assess the long-term effects of not wearing gloves on workers. Ergonomic and performance issues related to hand size, dexterity, and mobility as well as issues related to sanitation and deterioration require future analysis by manufacturers.

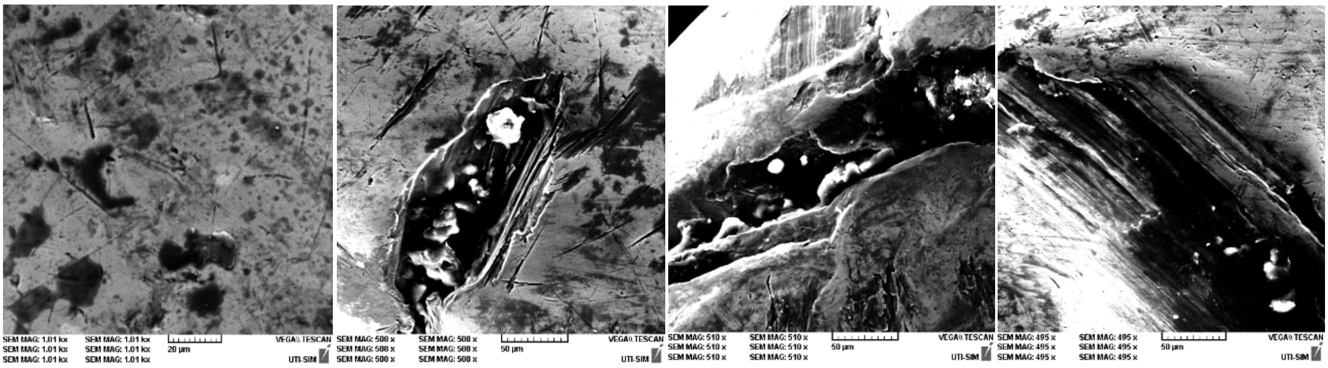
a) b)

Fig. 2. Metallic rings with defects identified by optical macroscopy a) Kosarom and b) Sellgros butcheries

In Fig. 3 few examples of defects identified on the metallic rings of the gloves after 2 years of usage are presented in comparison with an initial, not used, surface of a new ring glove, Fig. 3a).

As glove metallic material a stainless steel was identified with 18%wt. Cr and 8%wt. Ni. Beside some minor scratches from production process no other marks were identified on the surface, Fig. 3a). In all cases of the metallic rings extracted from the damaged areas, Fig. 3b)-d), on the surfaces are observed deformed areas, large scratches probably from the contact of a sharp object like a knife with the metallic glove. Beside the scratches in the same area different non-metallic materials can be observed as oxides form on the surface or traces of biological materials, Fig. 3b)-d). In case of the materials used in food preparation and in the same time protection of the human workers the materials used need to have a high corrosion resistance, the rust appearance is considered very dangerous and in the same time resistant at mechanical solicitations. Stainless steel represents a very good material opportunity for these applications. In TABLE 1 the surface chemical composition of the metallic rings is presented, comparatively with the initial state, the analysis was performed using an energy dispersive detector (EDS) in five different areas and the average values given.

After two years of usage the used glove rings, selected from the damaged areas, present a large content of carbon, especially on Kosarom glove, probably because of the biological remains from the processed material. In the same time, TABLE 1, a percentage of oxygen is observed on the surface, especially on the deformed area, Fig. 4b)-d). the presence of Oxygen element is based on the oxidation of the surface in the area damaged. For



a) b) c) d)

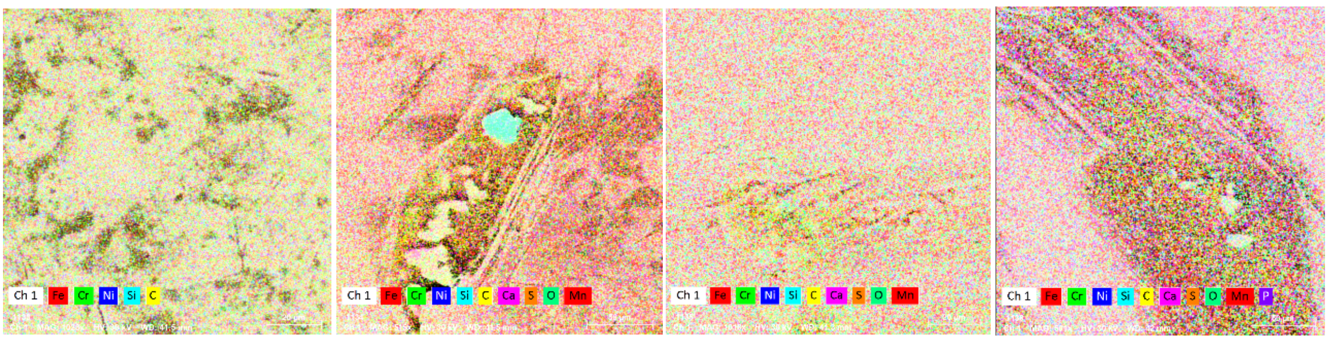
Fig. 3. SEM images of the metallic glove rings Initial state, Kosarom after 2 years, M&R after 2 years and Sellgros after 2 years

TABLE 1

Chemical composition on the metallic ring of the gloves: initial, clean one, and the others used after 2 years in Kosarom, M&R and Sellgros

Sample/ elements	Fe %		Cr%		Ni%		Si%		C%		O%		Others%
	wt.	at.	wt.	at.	wt.	at.	wt.	at.	wt.	at.	wt.	at.	wt.
Initial	73.1	72	18.7	19.9	7.7	7.2	0.5	0.9	—	—	—	—	—
Kosarom	44.2	20.1	11.1	5.4	7.2	3.1	0.6	0.5	27	57	5.4	8.6	F:3.2; S:0.4; Ca:0.1
M&R	51.8	26.9	12.8	7.16	7.4	3.5	0.4	0.4	22.4	54	3.8	6.8	S:0.4
Sellgros	54.3	30.3	13.1	7.9	8.2	4.3	0.57	0.63	19.3	50.2	2.8	5.4	S:0.5
EDS error %	1.5		0.4		0.3		0.09		3.8		0.8		F:0.01; S: 0.06; Ca: 0.05

St.Dev.: Fe±1.8; Cr:±0.8; Ni:±0.5;Si:±0.1; C:±2.5; O:±2; F:±0.1; S:±0.05 and Ca: ±0.01



a) b) c) d)

Fig. 4. Elements distributions on the surfaces of the stainless steels rings a) initial, b) Kosarom, c) M&R and d) Sellgros

stainless steels (SS) oxidation occur when the protective CrO_2 is damaged by mechanical external forces and the oxygen from the environment atmosphere attack the iron matrix [13-15]. The passivation layers' growth on SS surfaces, usually only of a few nm thickness at RT (room-temperature), are formed in a double type mode having an external film with more Fe-based oxides and the interior film is with more Cr-based oxides [6,7,16]. The non-corrosive properties of the SS are given by the Cr-based oxides layer which has a role to block the attack of ions from the solutions or from the near atmosphere [9,10,17].

Other elements identified on the surface are F, Ca and S mainly from the contact of the protective metallic glove with the other tools from the work station. Usually the temperature from these environments enhance the oxidation of the stainless steel which can recover his protective Cr-oxides based layer if the glove is kept in a clean environment for 3-4 hours without a corrosive environment to attack the iron matrix of the material.

4. Conclusions

Few metallic gloves for protection of the butchery workers were analyzed after two years of usage in meat processing field. Macroscopic few defects were identified on the surface of the stainless steel rings of the gloves selected from the damaged areas. All surfaces present defects created by external forces that cause also the oxidation of the area destroying the Cr-oxides protective layer and attacking the iron matrix of the 18Cr-8Ni stainless steel. The working conditions contribute to the deterioration of the protective glove decreasing considerably her working life-time period.

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