Functionalization with mineral fillers of cut resistant materials - a biomimetic perspective

Paulina Kropidłowska [1)], Emilia Irzmańska[1)], Jacek Sawicki[2)]

[1)]Central Institute for Labour Protection - National Research Institute (CIOP-PIB Poland)

[2)]Technical University of Lodz Institute of Materials Science and Engineering, Lodz University of Technology, 1/15 Stefanowskiego, Lodz, Poland

Introduction

One way of preventing hand injury is the use of gloves that are fit for purpose in protective and ergonomic terms [1-2]. Except for some specialist protective devices (such as metal mesh gloves), cut-resistant gloves are usually manufactured among others from p-aramid yarns or core spun yarns, polyethylene yarns, glass fibers, a combination of the above [3]. The design of protective devices is becoming an increasingly complex process requiring interdisciplinary knowledge in terms of both product development and assessment, going beyond the prescribed standards. An example of such an approach is seeking inspiration for innovative technological solutions in the natural environment [4-5]. Indeed, according to a substantial body of research, bionics-inspired solutions can substantially enhance mechanical properties as compared to conventionally engineered ones [6-7].

Materials and methods

The objective of the research is to improve the safety performance of protective gloves by increasing their cutting resistance using mineral fillers and bionic inspirations by modeling the surface structure of textile materials.

Biological analogies were implemented by the functionalization of textile materials. Inspiration was drawn from the scaly skin of reptiles and from the scute-based protective systems found on the skin of some placental mammals (fig. 1). Nature-inspired convex structures were obtained by the application of polymeric pastes (fig. 2) with additives differing in terms of chemical composition and grain fraction.

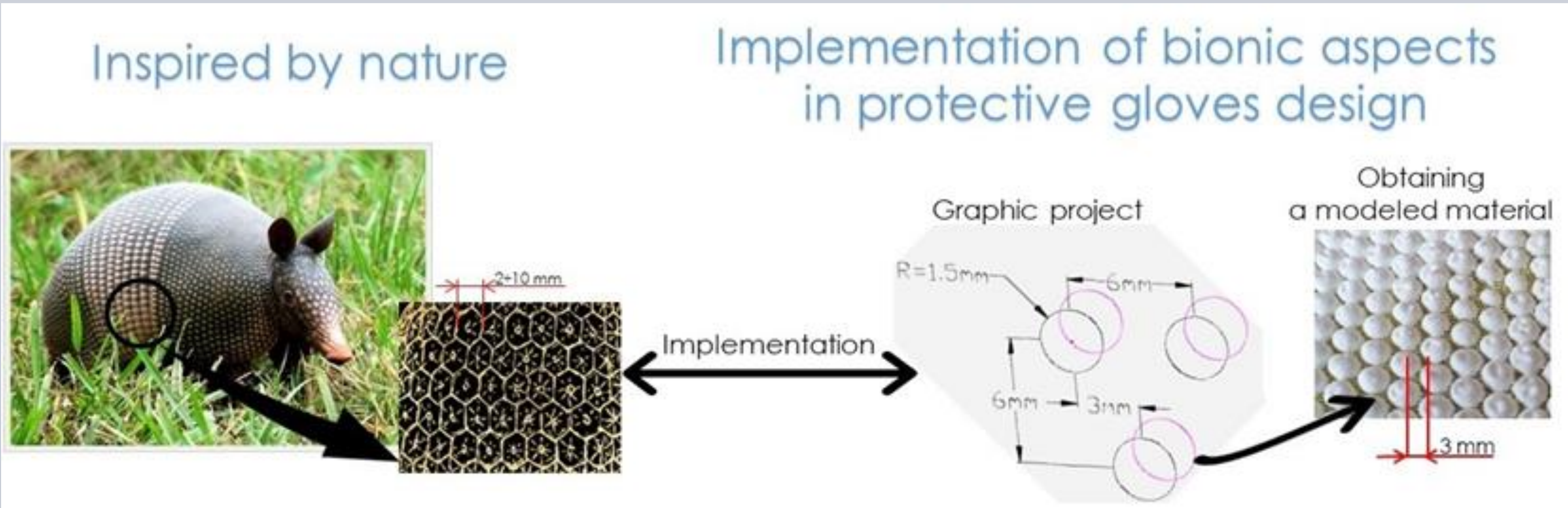

Fig. 1. Implementation of a biological analogy in the process of modeling bionic structures for application in cut-resistant protective gloves

The polymer paste was functionalized by the addition of 12 types of mineral fillers (fig. 3) belonging to four groups of compounds aluminium oxides, silicon carbides, calcium silicates and glass particles, with a size between 10 μm and 750 μm.

Fig. 2. Examples of modelled surface inspired by bionic structures - real life images

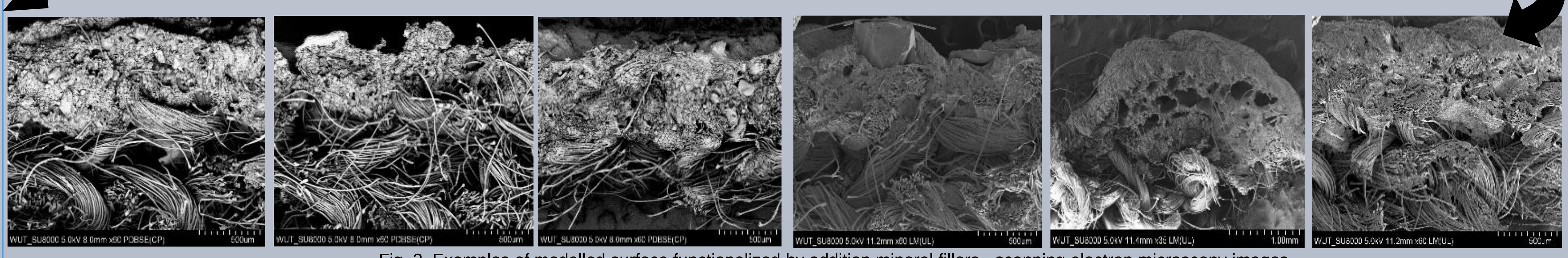

Fig. 3. Examples of modelled surface functionalized by addition mineral fillers - scanning electron microscopy images

To evaluate the cut resistant standard methods were used – EN 388 and EN ISO 13997 (in testing methods applied a round cutting blades and straight blades with variable cutting force).

Results and conclusions

A significant increase in the cut resistance of functionalized aramid knitted fabric with a coating layer inspired by nature was observed. Test results acc. to EN ISO 13997 are presented on (fig. 4). Based on the analysis of the microstructure of the functionalized materials containing mineral fillers, it was found that the layers with the lowest thickness, which penetrated into the structure of the knitted fabric, formed the most effective barrier to the blade in cut resistance tests.

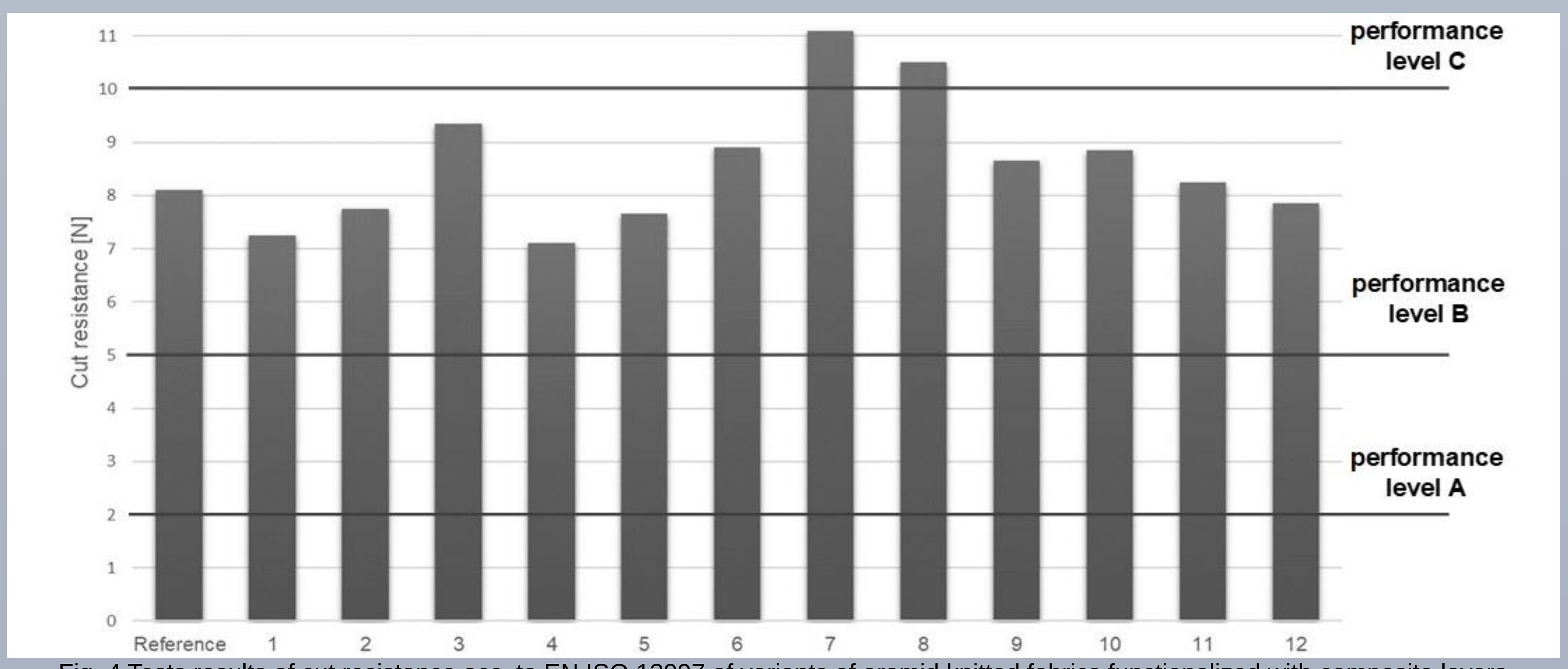

Fig. 4 Tests results of cut resistance acc. to EN ISO 13997 of variants of aramid knitted fabrics functionalized with composite layers with mineral fillers

Acknowledgements

This paper has been based on the results of a research task carried out within the scope of the fifth stage of the National Programme "Improvement of safety and working conditions" partly supported in 2020–2022 — within the scope of research and development — by the Ministry of Science and Higher Education /National Centre for Research and Development. The Central Institute for Labour Protection – National Research Institute is the Programme's main co-ordinator.

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