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COATING FUNCTIONALIZED WITH SILICON CARBIDE FOR CUT-RESISTANT PROTECTIVE GLOVE

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ABSTRACT

Workers' hands are at the highest risk of being affected by harmful factors in the work environment and upper limb injury is the most widespread type of workplace accident occurring during the performance of manual tasks. The protective properties of glove materials may be improved by continuous or spot coating [1–2] with polymeric materials such as poly(vinyl chloride), polyurethane, silicone, and natural or nitrile rubber [3–6]. The objective of the present work was to evaluate the effects of different size of particles added to a polymer material applied onto a textile carrier on the cut resistance of the resulting material. Knitted aramid textile samples were coated in laboratory conditions using a polymer paste that was functionalized with silicon carbide (SiC) reinforcing particles of three different size fractions. On the basis of the research it was found that the smallest size of SiC particles had the greatest effect on increasing cut resistance.

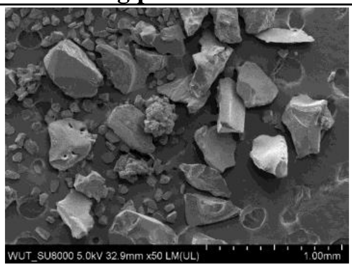
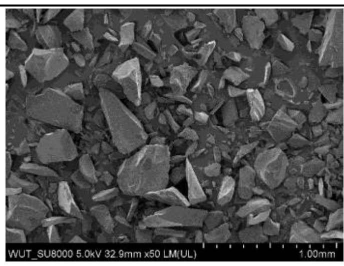
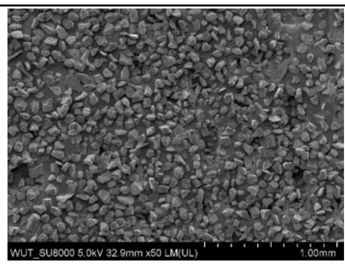
KEYWORDS

Functionalized coating, knitted textile, protective gloves, silicon carbide.

MATERIALS AND METHODS

The study material consisted of spot-coated textile samples fabricated in laboratory conditions. The textile carrier was a knitted aramid fabric (S.I. ZGODA, Poland) with a surface density of 234.1 g/m^2, a thickness of 0.23 mm. The composite coatings were made using an acrylic-styrene polymer paste (Thotex Sp. J., Poland) with particulate particles (Table 1).

Table 1. Reinforcing particles - silicon carbide.

SEM image			
Particle size	**150-450 µm**	**100-400 µm**	**50-75 µm**

For fixing of the coating elements samples were heated in a circulating air laboratory oven (Zalmed, Poland) at 140°C for 10 min [7]. Subsequently, the samples were removed from the oven and the homogeneity of the coating elements was evaluated. The reference material consisted of a textile carrier spot-coated with the polymer paste without particles.

Cut resistance was tested with a straight blade using a tonodynamometer (Kontech, Poland) according to the standard EN ISO 13997:1999 [8]. The cut resistance of materials expressed as the cutting force that is required to be applied to a blade of standard sharpness to just cut through the material in a 20 mm blade stroke (Table 2). At least twenty measurements are made on each sample using new blade for each cut.

The cut resistance test is conducting as follow: (a) apply a selected force progressively between the specimen and the blade; (b) make trial cuts tests to establish a force resulting in a cutting stroke length between 5 mm and 50 mm; (c) repeat tests with different forces until at least 15 readings have been obtained with cutting stroke lengths distributed between 5 mm and 50 mm; (d) normalize cutting stroke length by multiplication blade sharpness correction factor and recorded stroke length; (e) use calculated force to obtain at least five cutting stroke length between 18.0 and 22.0 mm and include these results in a recalculation of the cutting force. Testing samples were mounted on a cylinder with a radius of (38 ± 0.5) mm. Prior to testing, the samples were acclimatized at (23 ± 2)°C and a relative humidity of (50 ± 5)% for 24 h.

Table 2. Performance levels for cut resistance [9].

Performance Level	Level A	Level B	Level C	Level D	Level E	Level F
Cutting force [N]	2	5	10	15	22	30

Additionally the microstructure of cross-sections taken from the sample was assessed. Microstructure was examined using a SU-8000 scanning electron microscope (Hitachi, Japan) in the magnification range of 30–500× at an electron acceleration voltage of 5 kV.

RESULTS AND DISCUSSION

The studied variants of knitted fabric functionalized with composite layers exhibited cut resistance corresponding to performance levels B and C. Figure 1 presents the results of cut resistance tests for the test textile carrier functionalized with composite coatings.

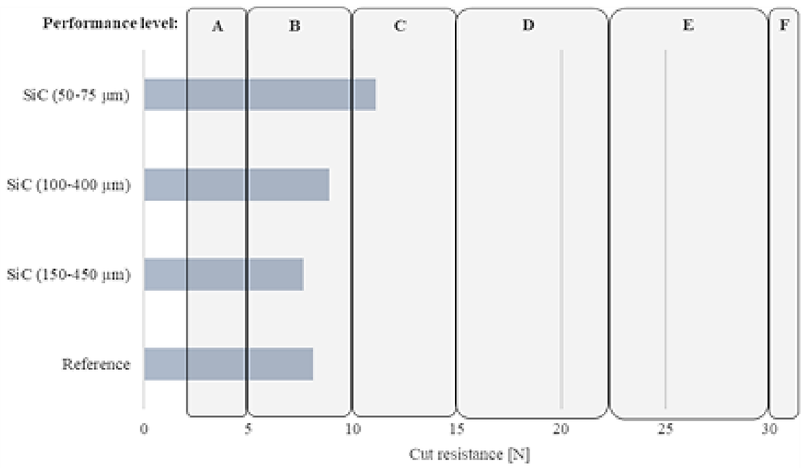


Figure 1. Cut resistance results.

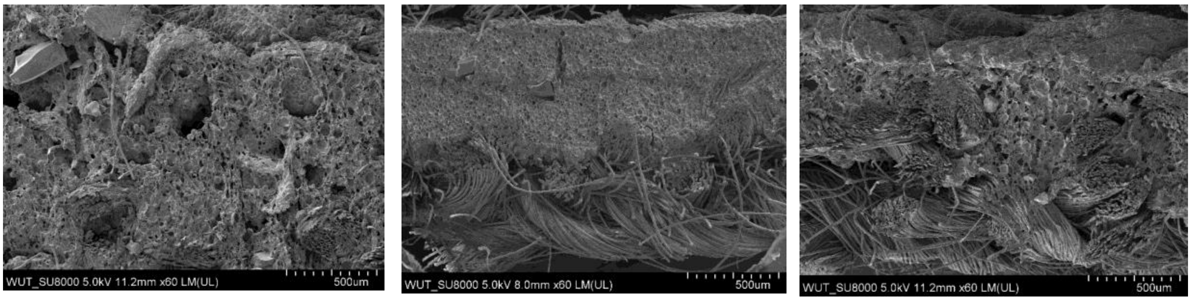
The tests evaluated the effects of reinforcing particles on the level of cut resistance offered by the materials. The highest cut resistance values were found for the variants incorporating 53–75 µm SiC particles (11.1 N) placed them at performance level C. Variants containing 50-450 µm SiC particles showed cut resistances (8.9 N). Statistical analysis confirmed the significance of differences between the studied particles in terms of their effects on cut resistance. In the present study, a knitted aramid carrier was functionalized with a composite coating. Continuous and discontinuous polymeric coatings have been previously applied to improve glove properties, and especially abrasion and cut resistance [10]. Matković et al. [11] applied a continuous polyurethane coating onto knitted fabrics to improve their mechanical properties. Mayo et.al. [12] reported that laminated fabrics exhibited higher cut and stab resistance than non-coated materials.

In the present study, an acrylic-styrene paste with a foaming agent was used to a specific geometry and thickness. All samples were made with one type of polymer paste incorporating particulate silicon carbide reinforcing particles (Table 1) with particle sizes ranging from 50 µm to 450 µm. Nunes et al. [13] investigated the effects of silica on the mechanical properties of an elastomeric mix, especially in terms of hardness and Young modulus. The effects were found to be strongly associated with the presence of silane groups on the surface of silica.

The authors concluded that the greater the surface density of silanol groups, the stronger the elastomer. The stab resistance of aramid composite fabrics with a thermoset coating containing SiC particles was evaluated by Rubin et al. [14]. The presence of SiC particles was found to improve stab resistance with the highest effectiveness at a concentration 20 wt.%.

Microstructural investigations revealed SiC particles to be embedded in interstitial spaces. According to Rubin et al. [14], the improved stab resistance was attributable to increased friction between the fibers, which may have blunted the blade. Literature reports have indicated that the cut resistance of knitted fabrics can be improved by modification with additives (e.g., SiC). Research has also shown that of the essence is the size of particles added as well as their percentage share in the coatings [15–17].

In the context of these findings, it should be noted that Gent and Wang [17] showed that the energy of cutting through polymeric materials consists of two components: the energy needed to break molecular chains and the energy of viscoelastic and plastic deformation (depending on the type of material). Moreover, according to the literature cut resistance largely depends on the friction between the material and the blade. Importantly, a higher friction coefficient may either increase or decrease cut resistance, depending on the properties of the material, including its thickness and microstructure [18]. To explain the observed cases of diminished cut resistance, the present authors additionally performed microstructural examinations using scanning electron microscopy.



(a) (b) (c)

Figure 2. SEM image of coating incorporating SiC with a particle sizes: (a) 150–450 µm (b) 100–400 µm (c) 50–75 µm.

In the case of the coating containing SiC, cut resistance decreased with increasing additive particle size [7]. It was also found that the finer the particles, the thinner the composite layer and the better its fiber wetting properties (Figure 2a–c). As regards the SiC particles, the highest cut resistance was found for 50–75 µm particles (Figure 2c).

CONCLUSION

This study presents functionalized materials designed to improve the cut resistance of protective gloves. A knitted fabric carrier was coated with a composite paste containing silicon carbides particles of different size. The greatest increases in cut resistance were found for SiC (53–75 µm), which was the smalless size of particles. Particle size was found to affect the porous microstructure of the polymer paste and cut resistance properties [7].

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