Mineral fillers for functionalization composite layer for textile coatings to improve cut resistance

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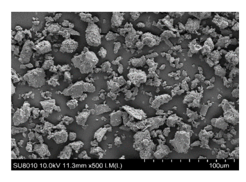
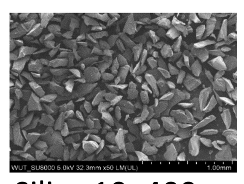
INTRODUCTION

The functionalization of polymer coating layers for textile materials, including those used in Personal Protective Equipment, can be achieved through physical or chemical surface modifications and by incorporating nanoparticles.

Mineral fillers such as basalt and silica can be use to improve the mechanical properties of polimer [1]. Composites reinforced with basalt nanoparticles have improved mechanical and thermomechanical properties. In addition, the use of powdery basalt rock as a filler in the coating layer improves cut resistance. The use of powdery basalt rock as a filler in the coating layer improves cut resistance [2].



Basalt 1-45 µm



Silica 10–400 µm

Fig.1. Scanning electron microscope images of mineral additives

AIM OF THE STUDY

The main aim of the study was:

- application of mineral fillers for functionalization a composite coating layer to improve cut resistance,
- evaluation of the influence of coating layer geometry on anti-cutting properties.

MATERIALS

- Latex paste with five different concentrations of mineral filler were prepared. The maximum filler concentration allowing homogeneous integration with the polymer paste was 2.5 %, therefore higher concentrations were not presented in the study. The filler was combined with the latex paste by mixing in a laboratory stirrer at 1200 rpm for 5 min.

Sample	W0	W1	W2	W3	W4	W5
Concentration in latex paste [%w/w]	0.0	0.5	1.0	1.5	2.0	2.5

- The object of the study was an aramid knitted fabric with a geometrized structure, obtained by applying a polymer coating using designed pattern matrices. The matrices were various in terms of geometric pattern and density of elements forming the three-dimensional structure. Tests were performed for materials with three types of geometry (E-ellipse, R-rhombus, C-stripes) in three size variants (1-smallest, 2-medium, 3-large). Size was increased by 50% relative to each other while the distance between the edges was constant.

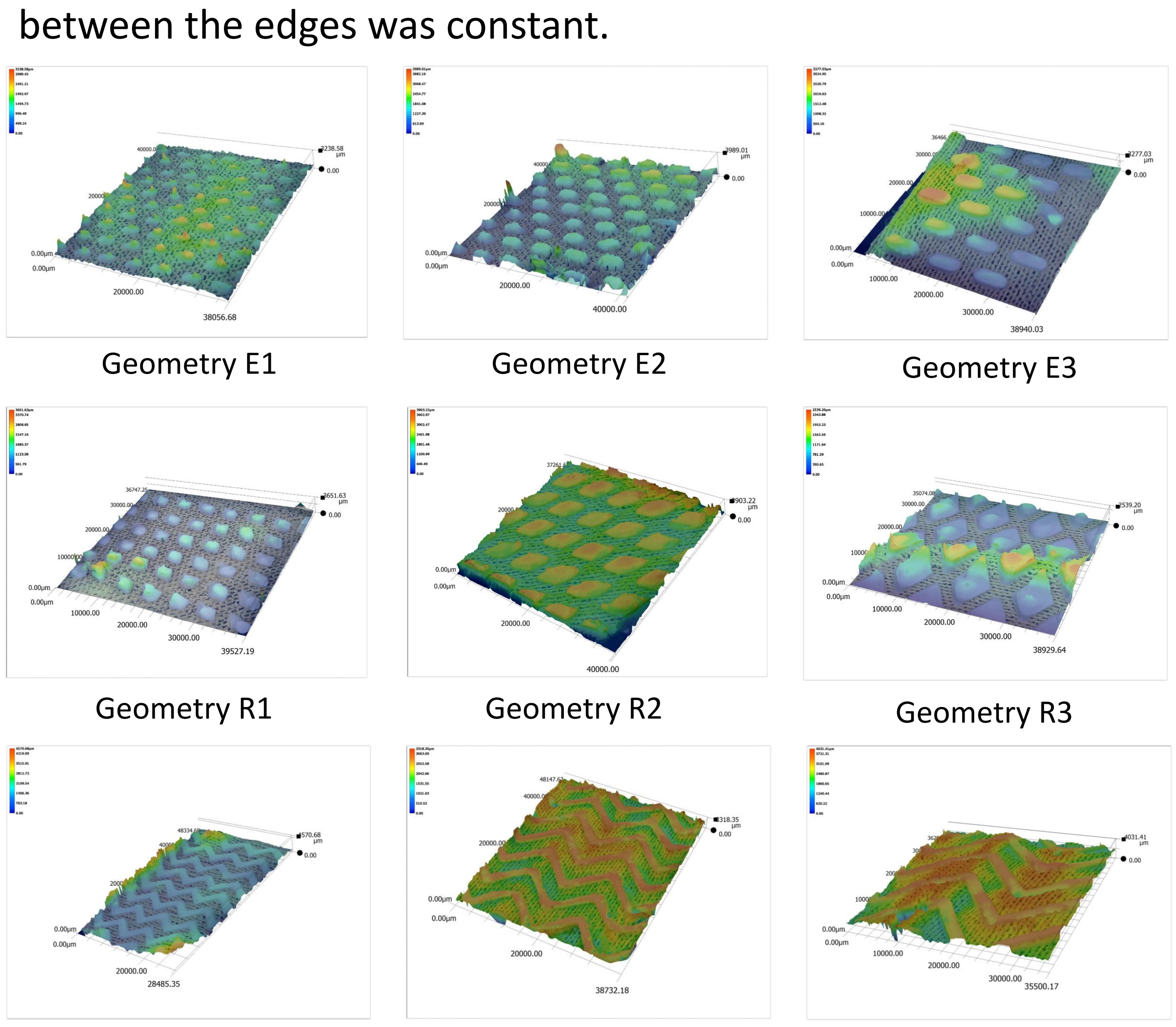


Fig. 2. Topography of the composite layer coating the knitted fabric in 3 variants of geometry.

METHOD

- Determination of the viscosity–shear rate dependence were measured using a Physica MCR-301 cone-and-plate rheometer (Anton Paar, Graz, Austria) with a diameter of 25 mm and a cone angle of 1° (CP 25) at 25°C.
- Cut resistance was tested according to the standard EN ISO 13997:2023 using a tomodynamometer equipment (Kontech Ltd, Poland) with load ranges from 1.0 N to 30.0 N and a cutting speed of 2.5 cm/s. Blades were made of stainless steel (hardness above 50 HRC) - length 70 mm and angle 22° at the cutting edge.

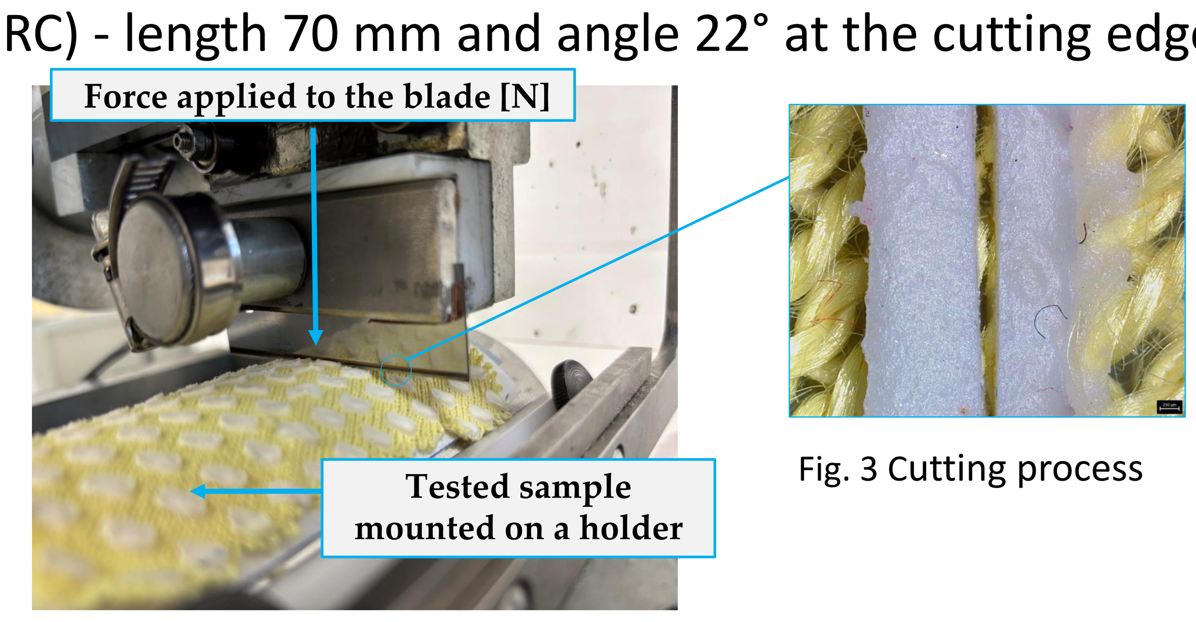


Fig. 3 Cutting process

- Microscopic analysis was conducted using optical (OPTA-TECH, Poland) and electron microscopy (HITACHI SU-8010, Japan) to assess coating geometry and porosity.

RESULTS

- Functionalization of a composite coating layer by application of mineral fillers to improve cut resistance was evaluated by defining the relationship of viscosity as a function of cut resistance. The presented study indicates that the addition of mineral filler to the polymer matrix modifies its protective properties and increases cut resistance.

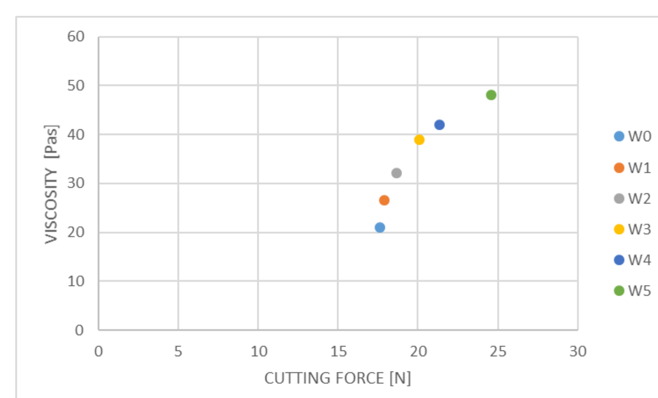


Fig. 4 Viscosity as a function of cut resistance

- Cut resistance results indicate that rhombus-geometry coating (R) exhibited the highest cut resistance, with values increasing from 10.9 to 24.0 N - a 54% increase.

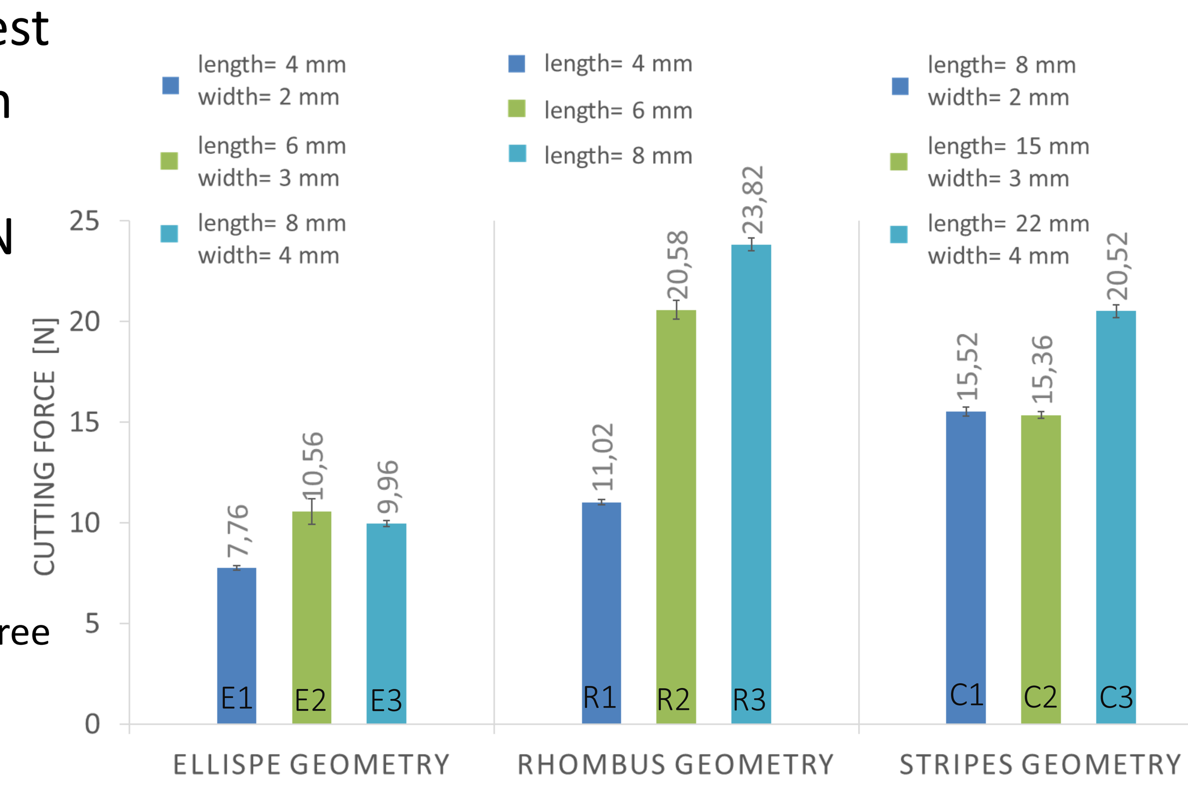


Fig. 5 Cut resistance of three types of coating layer geometry

Mineral fillers increased the integrity of the composite layer and reduced the porosity.

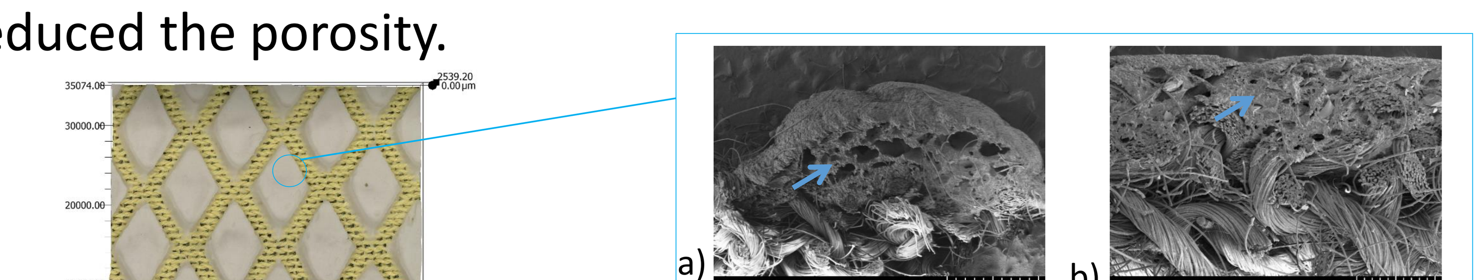
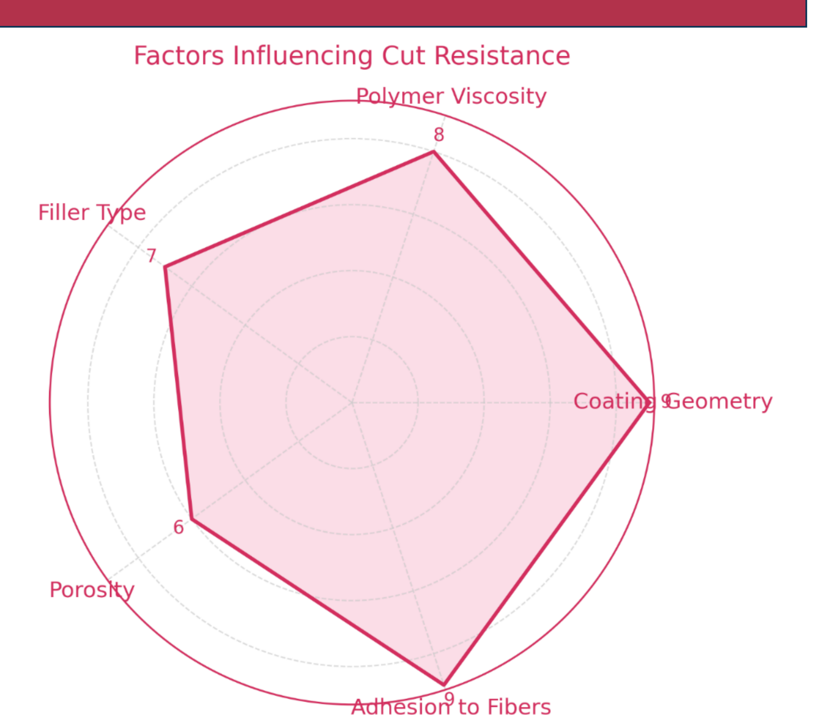


Fig. 6 SEM and optical visualization of the coating layer structure a) reference , b) with mineral filler

CONCLUSION

The incorporation of mineral fillers into composite layer for textile coatings significantly improves cut resistance. The enhanced performance is related to optimized geometry, increased viscosity and filler-fiber interaction, which reduces porosity and increases mechanical resistance.



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