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Considerations on modifying basalt fabrics protecting against the thermal radiation

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ABSTRACT

Due to very good thermal and mechanical properties characterizing basalt fibers and items made of them, this raw material is now more frequently used for the manufacturing various textile products. Basalt fibers on the textile market are primarily used in articles, which are designed to protect against thermal factors. The paper discusses the possibility of applying selected coatings formed by physical – PVD (Physical Vapour Deposition) or chemical CVD (Chemical Vapour Deposition) deposition of chemical compounds in the form of gaseous phase on the surface of basalt fabrics to improve their protective properties against very high temperatures affecting the clothing products.

***Keywords*:** basalt fibers, physical vapour deposition, chemical vapour deposition, basalt fabrics, protective gloves

1. INTRODUCTION

Nowadays, due to a rapid technological advancement on the textile and clothing market, new, more innovative textile products are constantly being produced and made available. Modern techniques and technologies are primarily implemented into manufacturing the clothing in order to provide the user with better functionality of the product under specified conditions and to ensure improved comfort during the use. Due to their excellent thermal and mechanical properties, including significant resistance to high temperatures basalt, fibers can be applied in specific parts of protective garments or in the whole clothing items. Due to the

potential application of modified basalt fabrics in the palm part of the protective glove, the main research task is to improve their protective properties. As the target group of such gloves are metal- and glassworks employees and people dealing with thermal processing of materials, the main aim in gloves manufacturing is to improve their protection properties against the high temperatures and contact heat resistance.

So far studies on this issue have been conducted by the Central Institute for Labor Protection in cooperation with the Lodz University of Technology. In the conducted tests, it was proposed to use basalt fabrics coated with an aluminum foil. However, after analysis of the obtained results, it was found out that this structure cannot be applied in the palm part of the protective glove, protecting against thermal and mechanical factors, due to its low resistance to the contact heat. Thus, the structure of the protective glove developed during the tests, based on the use of aluminized basalt fabrics, was applied in the outer part of the glove [1-3].

The Institute of Architecture of Textiles of Lodz University of Technology has carried out research on the selected issues concerning the use of aluminized basalt fabrics for specialized protective clothing. An analysis was conducted which proved that these fabrics are characterized by thermal insulation properties better or similar to those of glass fabrics [4]. These results allowed us to conclude that the tested aluminized basalt fabrics can be applied in the production of protective clothing designed to protect against high temperatures [4,5].

2. MATERIALS AND METHODS

Description of research object - state of knowledge

Gloves protecting against thermal factors are primarily produced from aramid, glass, as well as cotton, wool and aramid-cotton fabrics with anti-flammable finishing. Heat-resistant leathers are also used for manufacturing gloves protecting against high temperatures [6].

Basalt fibers are characterized by:

- high resistance to low and high temperatures,
- non-flammability,
- lack of odour,
- good dirt resistance,
- resistance to vibrations,
- good fatigue strength,
- good abrasion resistance compared with other materials,
- high strength and Young's modulus,
- low elongation,
- resistance to corrosion, UV radiation and micro-organisms,
- they are safe for humans and environmentally friendly,
- they do not require any chemical additives in the production process,
- articles made of these fibers do not emit any toxic products in reaction with air or water,
- without proper coating, basalt fabrics can irritate eyes, respiratory tract and, above all, cause a skin redness and irritation [7].

Table 1.Characteristics and comparison of properties of basalt and glass fibers [8]

Parameter	Unit of measure	Fiber	
		Basalt	E-glass
Thermal			
Application temperature	°C	from –260 to +560	from –60 to +460
Maximum temperature of short-term work	°C	to ÷700	to ÷ 550
Thermal conductivity,	W/m K	0,031-0,038	0,034-0,040
Thermal expansion coefficient	ppm/°C	8,0	5,4
Mechanical			
Tensile strength	MPa	4800	3400
Elasticity modulus	GPa	89	77
Elongation at breaking	%	3,1	4,7
Stability under tension (400 °C)	%	82	52

Figure 1. Basalt fabric with twill weaves

Basalt fibers are an attractive alternative to some high-performance fibers (Table 1) due to their good resistance to high temperatures as well as various chemicals.

Basalt textiles are widely used in many areas, including acoustic insulation, construction industry - mainly for a concrete reinforcement, chemical and petroleum industries or as

filtering materials. Additionally, such fibers are frequently used for polymer composite reinforcement and as polymer fillers [8].

Fabrics obtained from basalt fibers (Fig. 1), thanks to their properties, are suitable for the use in articles protecting against heat and fire [7]. In addition, they are used to reinforce roads surfaces, in shipbuilding and petrochemical industry, mainly as filtration materials, or serve as flame retardant curtains [8].

Textile materials made of basalt fibers are attractive due to the technological solutions as well as their properties, which make them useful in manufacturing the protective clothing, such as gloves protecting against high temperatures.

In addition, basalt fabrics are less expensive to manufacture compared with other fabrics, such as carbon or aramid ones, and thus the final product can be obtained cheaper [6].

3. RESEARCH METHODOLOGY

Surface engineering is a field of science, which has evolved significantly over the last years. As a result of intensive technological development, modern surface protection methods have been developed, and are being further refined by professionals working in that field of science, in order to obtain layers with the varied thicknesses, properties and structural and physical parameters [9].

In order to modify basalt fabrics it is possible to coat their surface by means of physical and chemical vapour deposition. The first method relies on producing a coating on a selected substrate by physically depositing atoms, molecules or ions of certain chemical compounds. Due to the way of obtaining the deposited layer, we can distinguish the following types of physical deposition: spraying, evaporation and sputtering [10].

The process of physical vapour deposition is carried out in a vacuum. In this process we can distinguish three stages:

- transition of the deposited material into the vapour,
- transport of the material in the vapour state to the surface of the object,
- condensation of the material on the object and coating growth.

Coatings obtained as a result of physical vapour deposition are primarily used in optics, electronics, and machine design, where their main function is protection, particularly against the wear and corrosion. The coatings can also be used for a decoration. Physical vapour deposition enables obtaining very hard coatings, which are resistant to wear. Such coatings are applicable, especially when one of the main evaluation criteria is the high dimensional stability. In this process, the method of combining the coating with the substrate is usually an adhesion or less frequent adhesion-diffusion.

Modern technological devices used in the surface engineering, called sputtering machines, which are used to apply PVD coatings, enable a very precise control of this process as well as the structure, chemical composition and properties of the coating.

These properties depend mainly on the pressure of gases present in the chamber of the sputtering machine, temperature of the process, distance between the substrate and the deposited material, chemical composition of the material, which is deposited, the surface of the substrate and accelerating voltage.

The CVD process (chemical vapor deposition) relies on producing the coating as results of a chemical reaction of gases, located on the surface of the heated object. In this process the source of the applied substance is mainly gas or a solid. For this reason, the CVD process can also be defined as the process of depositing chemical compounds in the gaseous phase as a result of chemical reaction of solid and a certain surface of the heated object. In this process we can distinguish the following stages:

- production of a volatile compound,
- transport of the gas to the deposition site,
- Chemical reaction necessary to produce a layer on the substrate.

In this process metals and ceramics as well as diamond or diamond-like layers are mainly deposited. By applying CVD methods it is possible to obtain the abrasion resistant and, above all, hard nitride, carbide, oxide, and carbonitride coatings. These coatings are mainly used in the manufacturing of cutting and hot and cold forming tools. In chemical vapor deposition processes, atmospheric constituents are usually activated thermally or by using the plasma. We can, therefore, distinguish the following types of chemical vapor deposition: APCVD (atmospheric pressure CVD) - a process, in which atmospheric constituents can be activated at the atmospheric pressure, LPCVD (law pressure CVD) where activation takes place under the reduced pressure and PACVD (plasma assisted CVD), where the process of chemical vapor deposition is assisted by the glow discharge.

The CVD process is usually carried out at high temperatures above 900 °C, which results in deformation on steel products. Consequently, the heat treatment is frequently used after the process is completed.

The high temperature of this process favors a mutual diffusion of substrate atoms into the coating and back, and contributes to a strong connection between them. However, sporadically, fragile intermetallic phases may occur, which causes a significant deterioration of mechanical properties of the resulting coating.

CVD processes are carried out under the atmospheric pressure, unlike PVD processes, which require the high vacuum, in which the atoms making up the coating are moving. In the processes of physical vapour deposition, the substrate temperature is lower, so this process does not require any heat treatment [10].

4. CONCLUSIONS

Research on the possibilities of applying selected coatings modifying basalt fabrics protecting against the thermal radiation show the potential for using physical and chemical methods of vapour deposition.

Due to the intended application of modified basalt fabrics in the protective clothing accessories (gloves), the main criterion for choosing the method of coating deposition on the surface of the fabric, apart from the obtained protective properties, should be the availability of the technology, the cost of the process and the uniformity of the substance distribution on the fabric. These factors have a significant impact on the research concerning protective properties against the high temperature.

As a result of literature analysis, a possibility was noticed for using surface-modified basalt fabrics in the process of making-up garments. The proposed coating techniques do not

lead to any destruction of basalt fabrics, which is very important from the viewpoint of properties and intended application of these fabrics for specific garment parts or whole products.

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