ЦИВІЛЬНА БЕЗПЕКА

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ANALYSIS OF MODERN DESIGNS OF HEAT-PROTECTIVE HELMETS

We have considered the general requirements for protective helmets, as well as materials used in the process of their manufacturing. We have analyzed the modern protective helmets used by workers during work in areas with heat output. We have also provided the schemes of design elements of heat-protective helmets with different types of cooling.
Key words*: ventilation openings; water cooling; ventilator; carbon dioxide; heat-protective helmet.*

Розглянуто загальні вимоги, що пред'являються до захисних касок, а також матеріали, які використовуються при їх виробництві. Проаналізовано сучасні захисні каски, що використовуються працівниками на роботах у зонах з тепловиділенням. Наведено схеми елементів конструкцій теплозахисних касок з різними видами охолодження.
Ключові слова*: вентиляційні отвори; водяне охолодження; вентилятор; діоксид вуглецю; теплозахисна каска.*

Problem statement, analysis of recent research and publications

Head injuries are relatively common and amount to 3 to 6 % of all accidents in developed countries. They are often severe and lead to significant loss of working time due to incapacity for work (up to 3 weeks). Injuries can be caused by falling objects with sharp corners, such as a tool from a height of several meters, as well as head blow. As a result of various head injuries may occur: perforation of the skull under considerable force on a small area of the head, fracture of the skull or cervical vertebrae with a strong blow, brain damage without fracture of the skull as a result of brain displacement in the skull, leading to contusion, concussion, internal bleeding and cerebral circulatory disorders. The results of the analysis of accidents among metallurgical workers who wear protective helmets show that head injuries occur when the impact energy exceeds 100 J. Other types of injuries are less common, but they shall also be taken into consideration. Such injuries include burns from splashes of hot or aggressive liquids, molten metals, as well as injuries resulting from accidental contact of the head with current-carrying elements [1].

Thus, development of new types of helmets, which will protect workers' heads from blows, as well as additional protection from other mechanical impacts, heat and electric current in welding, surfacing of machine parts and other processes with significant heat dissipation, is a crucial task.

The helmet consists of a shell with a visor (or without it) and brim (or without it), a headgear, as well as internals. The shell is a main protective element that bears the main weight of blows. To provide greater strength the helmet shell may contain a stiffening rib. The visor is a small protrusion above the eyes, the size of the visor varies on different models. Brim may have small grooves for draining liquid or rolling sparks and scale.

All safety helmets are subject to mandatory certification. Only materials safe for human health can be used for their manufacture. No helmet element should have sharp corners, burrs or other defects that could injure or irritate the skin. Fig. 1 illustrates the main structural elements of a protective helmet design[1].

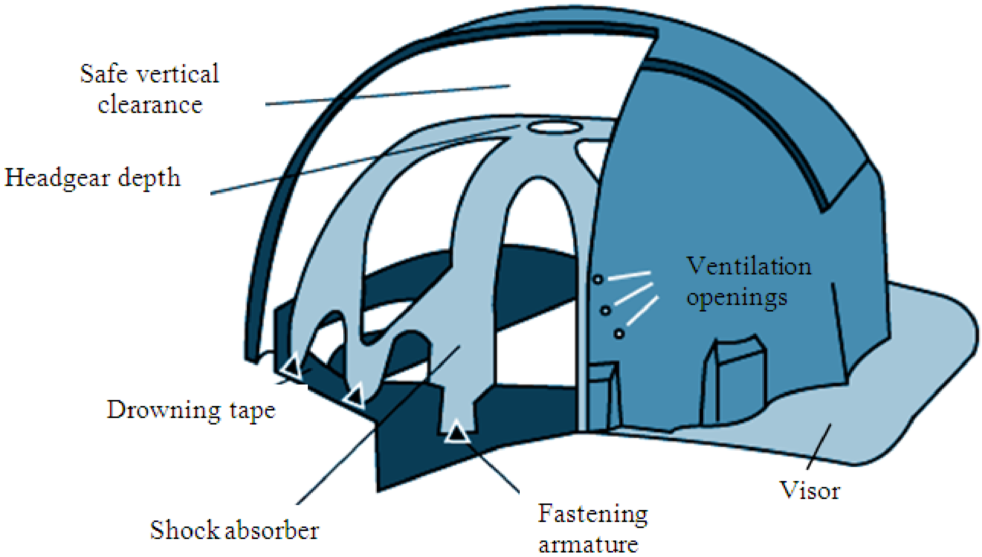

Fig. 1. The main structural elements of a protective helmet design

The following materials are used in manufacture of protective helmets:

– polyamide— a structural polymer with excellent antifriction characteristics and a large margin of safety, resistant to chemicals, sparks and metal splashes;

– ABS-plastic — shock-proof heat-resistant plastic, resistant to acids, alkalis, oils;

– low pressure polyethylene — a rigid polymer with a large margin of safety;

– high-pressure polyethylene — a weakly plastic material, not susceptible to the effects of aggressive media;

– monolithic polycarbonate — a material of high strength and impact resilience;

– fiberglass — a composite material with a very low thermal conductivity (for example, like wood), steel-like strength, biological resistance and resistance to changes in atmospheric phenomena.

Purpose statement

The aim of the work includes a detailed analysis of modern designs of protective helmets, which are used by workers during work in areas with heat output, studying the principles of protecting workers from excessive heat, as well as developing recommendations for improving designs of existing heat-protective helmets.

Statement of basic materials

At first, let's consider the modern design of a heat-protective helmet, where only ventilation holes are used for cooling.

Fig. 2 illustrates the main elements of the 3M G2000 safety helmet [2],that is subject to constant impact of ultraviolet radiation. It is made of ABS-plastic by means of pressure molding, has an ultraviolet indicator, a rigid structure, and provides free air circulation between the helmet structure and the mount. The ventilation openings located on the top of the helmet also provide additional ventilation. The UV absorption sensor informs on the need to change the helmet. The enlarged rear lower part provides additional protection for the neck. The helmet shape and its grooves provide means for attaching additional components (ear muffs, face shield, goggles, etc.).

This type of helmet is recommended for outdoor use, as well as in rooms with an internal temperature of up to 50 °C and in case of molten metal splashes.

In cases when the worker needs to perform work in an area of increased heat output, heat-protective helmets are used, considered below.

Fig. 3 illustrates the main elements of a heat-reflecting protective helmets with water cooling [3], which makes it possible to increase the efficiency of protection from thermal radiation while improving working conditions, as well as to increase the efficiency of worker's cooling by means of using material, that carries the heat away.

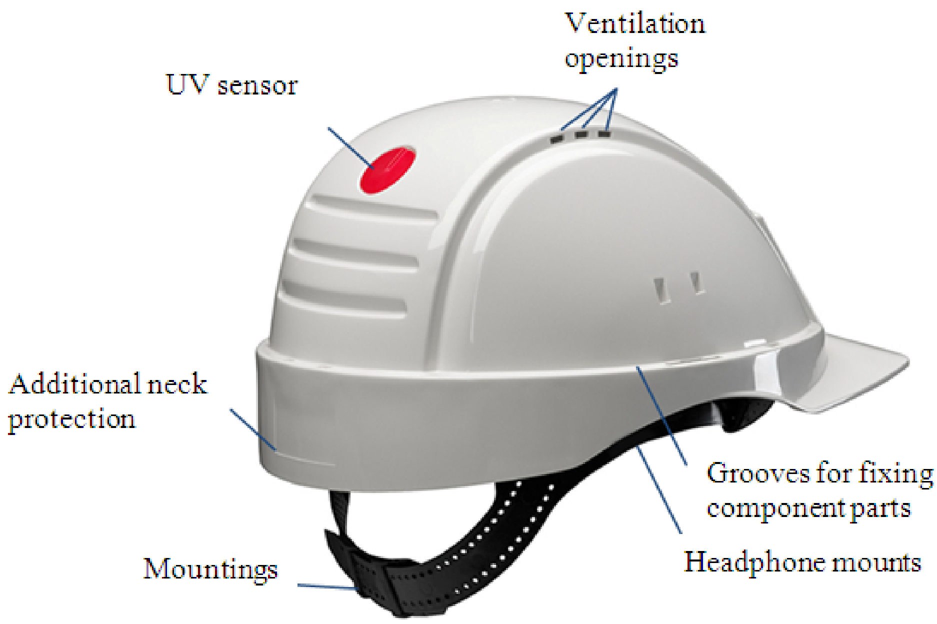

Fig. 2. The main elements of a 3M G2000 protective helmet

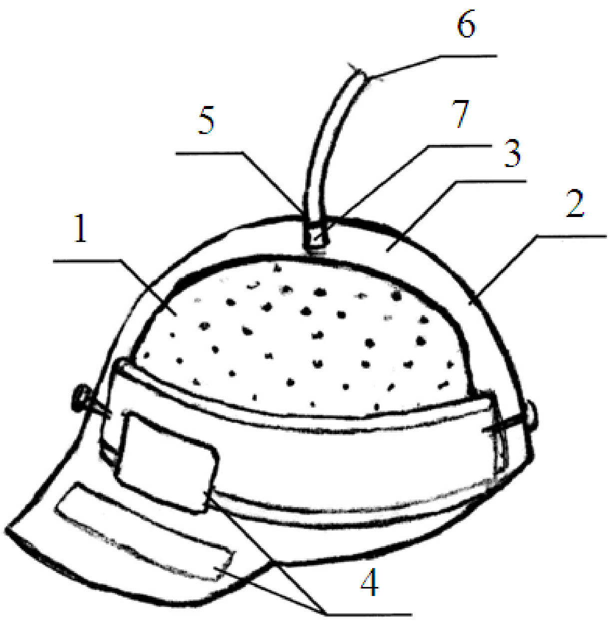

Fig. 3. Main elements of heat-reflecting safety helmet with water cooling: 1 and 2 — inner and outer surfaces; 3 — cavity between surfaces; 4 — shielding heat-reflecting segments; 5 — hole; 6 — flexible hose; 7 — nozzle

This helmet is water-cooled, contains inner and outer surfaces with cavities between them. Shielding heat-reflecting segments are installed on the outer surface of the helmet. The inner surface is perforated with a hole diameter of 1 mm, and on the exterior surface, in its central part, there is a hole with a rigidly fixed flexible hose. The second end of the hose is hermetically fixed in the cavity of the ball mixer, rigidly riveted in the lid with a hole in the cavity of the container filled with water.

Also, two flexible hoses are fixed in the cavity of the ball mixer, the lower edge of one is located at the bottom of the container, and the other, which has a handle with a nozzle at the end, is fixed on the container casing. In this case, a flexible hose is installed through the hole in the lid, one end of which is located in the upper part of the container, with a loose valve fixed inside it, and a pneumatic bulb is installed at the other end.

Before starting work, the operator pours liquid through the lid into the cavity of the container. Then he puts on the container casing, as well as a heat-reflecting helmet on the head and fixes on his belt with the help of a length-adjusting belt with latches. If it is necessary to cool the body, the operator creates in the cavity of the container the working pressure by means of a pneumatic bulb pumping air through a flexible hose. Thanks to the latter, the cooling fluid enters the cavity of the ball mixer. If necessary, the operator, using a ball mixer control, supplies cooling fluid either through a flexible hose to the nozzle of a heat-protective helmet, which sprays the cooling fluid on the perforated inner surface and then cools the operator's head, or via a flexible hose to the nozzle of a container with water, and then the operator can cool the necessary parts of the body at his own will (areas of heart, arms, face, chest and shoulders). Also, at the request of the operator, flow of cooling liquid can be directed simultaneously to both nozzles, which will provide simultaneous cooling of the head and body parts.

Contrary to the previous design of the heat-protective helmet, Fig. 4 illustrates the design of a heat-reflecting helmet with air cooling [4].

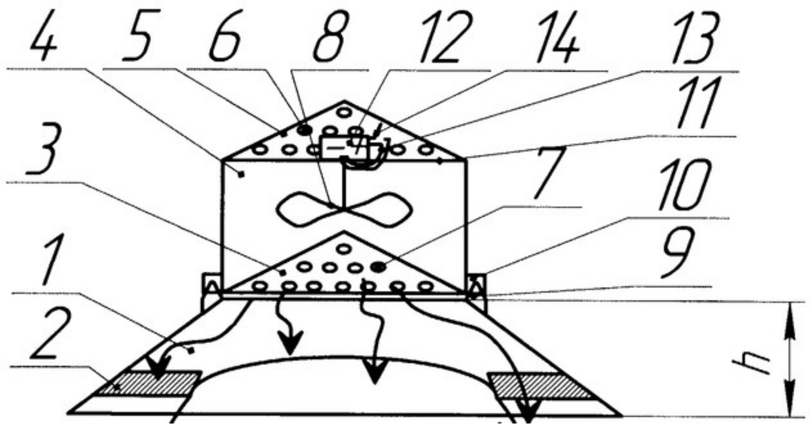

Fig. 4. The main elements of the heat-reflecting protective helmet with air cooling: 1 —lower part in the form of a frustum of cone; 2 — elastic soft pads; 3 — perforated cone of the lower part; 4 — the upper part in the form of a cylinder; 5 —perforated cone of the upper part; 6, 7 — ventilation holes; 8 —ventilator; 9 —holders (rods); 10 —conical bushings; 11 — rigid struts; 12 — rechargeable battery; 13 — wire; 14 — resistance switch

It contains ventilation holes on the outer surface of the helmet and installed shielding heat-reflecting segments, as well as a ventilator. This helmet is made of a component with the possibility of connecting its parts. The lower part of the helmet has the shape of a frustum of cone, on the inside of which there are rigidly fixed elastic soft pads in segments at equal distances from each other. The upper base is covered with a surface in the form of a perforated cone, the tip of which is directed upwards. The upper part of the heat-reflecting helmet is made in the form of a cylinder and ends with a perforated cone, the tip of which is also directed upwards. A ventilator is installed in the upper part of the helmet along the central axis. The batteries supply voltage to the ventilator via wires through a resistance switch. The intensity of blowing is regulated by frequency of rotation of the ventilator by means of the resistance switch. The entire outer surface of the helmet is covered with shielding heat-reflecting material.

The next two helmets have combined cooling and use carbon dioxide as a cooling fluid.

Fig. 5 illustrates the design of a SHS—1 heat-protective helmet [5, 6].

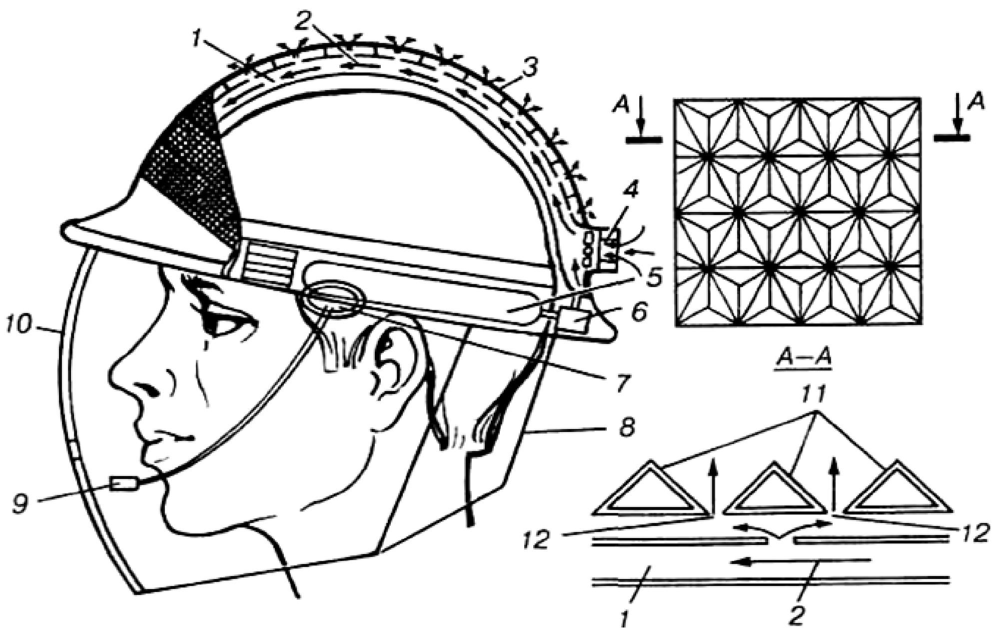

Fig. 5. The main elements of a SHS—1 heat-protective helmet: 1 — auxiliary cavity; 2 — compressed air; 3 — heat-reflecting screen; 4 —ventilator; 5 — carbon dioxide in the liquefied state; 6 — expansion chamber; 7 — system of a purified and humidified air supply to the human respiratory zone; 8 — protective fabric; 9 — spray of inhalation mixture drops; 10 — transparent shield; 11 — angle reflectors; 12 — hole

It has an auxiliary cavity 1 between its outer and inner surfaces, to which compressed air 2 is supplied by a ventilator 4, or carbon dioxide in the liquefied state 5. Carbon dioxide is used under extreme conditions, with very strong thermal radiation. It is supplied into the expansion chamber 6, where it evaporates and lowers its temperature to +5 °C. The entire surface of the protective helmet is covered with a special heat-reflecting screen 3, the basis of which are special angle reflectors 11, connected to one another. The recess of each reflector has a hole 12 of the auxiliary cavity 1, located in the recess of the angle reflector. The latter returns up to 97 % of the radiant heat that affects it, and compressed air or carbon dioxide cools its inner surface and blows dust from the recess. Such a helmet has an efficiency of about 97 % at external thermal radiation up to 10—15 kW/m^2.

Low humidity, harmful fumes, dust can cause coughs, asthmatic attacks etc. In order to prevent them, a heat-protective helmet has a system 7 with a sprayerof inhalation mixture drops 9 and the supply of purified and humidified air to the human respiratory zone.

A transparent shield 10 made of photochromic glass is used to protect the visual organs from the source of optical or infrared radiation, which changes its density depending on the intensity of optical radiation. The helmet has a soft protective fabric 8.

In addition to welding and cutting processes, helmet options shown in Fig. 3—5 are used during blacksmithing, surfacing of machine parts (shafts, excavator buckets, brake pulleys, etc.), melting of magnesium alloys, and others. The last helmet (Fig. 5) is also reasonable to be used when servicing heating units with a wide range of strong excess radiation, for example, during the internal repair of heating furnaces.

Conclusion

We have analyzed the modern designs of heat-protective helmets used by workers during work in areas with heat output. It is recommended to use the 3M G2000 helmet with cooling by means of ventilation openings in rooms with internal temperature to +50 °C and if any splashes of molten metal. Helmets with water, air and combined cooling (air and carbon dioxide) are used in the process of welding, cutting, forging and smelting. It is also advisable to use the SHS—1 helmet when servicing heating furnaces.

In the course of the analysis of the abovementioned heat-protective helmets it is possible to offer methods for improvement of their designs. First of all, it is a further reduction in the weight of the helmet by using modern materials that have excellent antifriction characteristics, high strength, resistance to chemicals, sparks and splashes of metal, biological resistance and weather conditions resilience, very low thermal conductivity, unaffected by aggressive media. The use of a two-stage system of dust and gas cleaning, which will capture dangerous compounds of manganese, fluorine and welding aerosol, is also promising.

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АНАЛІЗ СУЧАСНИХ КОНСТРУКЦІЙ ТЕПЛОЗАХИСНИХ КАСОК

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Реферат

Травми голови відбуваються відносно часто та складають від 3 до 6 % всіх нещасних випадків у розвинених країнах. Нерідко вони бувають важкими та призводять до значних втрат робочого часу внаслідок непрацездатності. Причинами травм можуть бути падіння предметів з гострими кутами, наприклад, інструменту з висоти кількох метрів, удари головою, опіки від бризок гарячих або агресивних рідин, розплавлених металів, а також травми, отримані в результаті випадкового дотику голови зі струмопровідними елементами. Таким чином, розробка нових видів касок, що забезпечить захист голови працівників від ударів, а також додатковий захист від інших механічних впливів, тепла та електричного струму, є актуальною задачею.

Метою роботи є аналіз та детальний розгляд сучасних конструкцій захисних касок, які застосовуються працівниками на роботах у зонах з тепловиділенням.

При виробництві корпусів захисних касок використовуються наступні матеріали: поліамід — конструкційний полімер з відмінними антифрикційними характеристиками та великим запасом міцності, стійкий до хімікатів, іскор та бризок металу; ABS-пластик — ударостійкий термостійкий пластик, стійкий до впливу кислот, лугів, масел; поліетилен низького тиску — жорсткий полімер з великим запасом міцності; поліетилен високого тиску — слабопластичний матеріал, не сприйнятливий до впливу агресивних середовищ; монолітний полікарбонат — матеріал високої міцності та ударної в'язкості; склопластик — композиційний матеріал, що має дуже низьку теплопровідність, міцність як у сталі, біологічну стійкість та стійкість до зміни атмосферних явищ.

В статті проаналізовано сучасні конструкцій захисних касок, які застосовуються працівниками на роботах у зонах з тепловиділенням. Каску типу 3M G2000 з охолодженням за допомогою вентиляційних отворів рекомендується використовувати в приміщеннях з внутрішньою температурою до +50 °С та за наявності бризок розплавленого металу. Каски з водяним та повітряним охолодження, а також з охолодженням за допомогою діоксиду вуглецю використовують під час проведення зварювання, різання, при ковальських та плавильних роботах. Каску типу СГС-1 також доцільно застосовувати під час обслуговування нагрівальних печей. При роботі в екстремальних умовах у зонах з підвищеним тепловипромінюванням рекомендується використовувати каску зі склопластику марки ДСР-4Р-2М.

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