OBTAINING OF NEW FIREPROOFED COMPOSITION MATERIAL

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According to theoretical consideration of metallurgists’ protective clothes reliability increase problem all the major questions, connected with obtaining of new kinds of composite materials and their properties regulated by special requirements, were experimentally studied. The choice of the research objects was defined by the primary goals following from results of theoretical research, concerning material physical mechanical properties conservation after its long contact with particles of the fused metal. The developed new composite material for protective clothes contains binding with each other by needle piercing method heat-shielding blade in the form of gray military cloth processed by fire retarder and silica fabric impregnated by siliceous structure - a powder of zoo slag, dissolved in liquid glass on face sheet of which the layer of aluminum is evaporated. On the basis of experimental research and theoretical generalizations it was proved that the protection of a fabric from damage at contact with liquid metal is possible by a finding of such components of fireproof structures, which prevent defeat (at their drawing on a surface of a suit) of the last due to thermal processes of decomposition with carbonization and intumescence. The gray military cloth, being a fabric from natural fibers, provides hygiene of the back layer of a composite material besides itself concerns to group of heat-resistant fabrics. The layer of the aluminum which has been evaporated on a face sheet of the impregnated silica fabric strengthens effect of molten metal drops kickback from a composite material, and also provides the maximal reflection of thermal radiation.

Keywords: metallurgists’ protective cloth, new fireproofed composition material, fire retarder.

INTRODUCTION

As a result of the last years, a critical situation has arisen related to the provision of workers with qualitative overalls made of fire-proof materials having higher operational properties. That caused the increase in cases of traumatism and occupational diseases. According to the statistical data of the R.K. Ministry of Labor, about 35% of workers are employed under adverse conditions, and the traumatism factor, owing to the non-compliance with the operational requirements for the quality of working clothes and fabrics, is 0.16 per 1000 workers, that is single-order higher than such index parameter across the USA and EU countries.

Subject to the «Typical branch standards of a free-of-charge release of overalls to workers and employees», the overalls from wool fibres given out to workers do not meet the requirements of a consumer for their operational properties, and they become useless already after 2-3 months instead of 9 month of operation due to the sparks of a smelt metal coming into the surface of overalls.

A new conceptual target setting is proposed for the increase in protective properties of overalls of workers of the metallurgical and metal-working industries, and of workers engaged in welding, by finding methods of a substantial reduction of adhesion of smelt metals to the surface of textile materials (from domestic raw material), as the main damaging factor. For this purpose, processing of fabrics with special substances is required, which impart improved operational properties.

In performing his operations, a metallurgist has no opportunity to be released from the particles of a smelt metal having come into his overalls. Therefore, a metal particle having a high thermal energy is on the surface of overalls releasing part of the energy to the ambient air and another such part is released through the protective clothes and linen
to the leather of the worker causing the raise in its temperature which after some limit can cause a burn. Thus, in order to reasonably operate designing of materials and clothes, one should know the rate of cooling of a smelt metal particle, duration of the process and the power of a superficial thermal flow coming into the worker’s body. To find answers to the set objectives, it is necessary, first of all, to know a heat-transfer factor $\alpha_{sc}$. liquid metal - air.

The heat-transfer factor can be found from the expression (1):

$$\alpha_{sc} = \frac{Nu \lambda}{l} \tag{1}$$

where $Nu$ – Nusselt number/criterion of similarity; $\lambda$ - coefficient of heat conductivity of the atmosphere; $l$ - characteristic size of the task, for example, radius. It is known that

$$Nu = c \cdot Re. ^{m} Pr ^{n} \tag{2}$$

where $c$ - constant of proportionality; $Re$-Reynolds number; $Pr$-Prandtl number; $m$ and $n$ - empirical exponents.

All necessary data for calculation can be consulted from the rules of the shop climate recommended by technical requirements (2).

Then, the quantity of heat $Q_n$ lost by a particle of a smelt metal owing to airflow can be calculated according to the Newton formula:

$$Q_n = \alpha_{sc} (t - t_0) S \tag{3}$$

where $t$ - temperature of a smelt metal; $t_0$ - temperature in the shop; $S$ – surface area of the smelt metal particle after its coming into the surface of the protective suit. Combining some expressions, we shall obtain the design formula for a characteristic time of heat abstraction $\tau_q$ into the air:
where $C_p$ - thermal capacity of the smelt metal at the melting temperature, $\rho$ - density of liquid metal, $\delta$ - thickness of a smelt and flattened drop of metal.

In this formula, the defining value is referred to heat-transfer factor $\alpha_{ac}$. The physical essence of the characteristic time of heat abstraction in seconds consists in the fact that it characterizes the rate of cooling of a heated body. The size $\tau_\alpha$ allows us to investigate dependence of the temperature of the smelt metal particle on the duration of the cooling process. If the temperature of a cooled body is $t^\tau$, time or duration of exposition is $\tau_\alpha$, $t$ - temperature of the smelt metal particle and $t^0$ - temperature of the ambient air, then it is easy to find:

$$t^\tau = t^0 + (t - t^0) e^{-\frac{\tau_\alpha}{\tau_\alpha}}$$

The formula (5) enables to calculate the temperature of the smelt metal particle at any moment if the heat goes out of the drop just into the air. In fact, the problem turns to be much more complicated, and it is necessary to take into account several heat-transfer processes at the same time.

Indeed, the thermal energy $Q^0$ of the drop of a smelt metal spreading flatly after contacting the solid surface of a fabric, is spent for generation of heat flows in the two opposite directions. One of the flows transfers part of energy to the air $Q^H$ flowing around the drop (due to free or compelled convection), the other flow transfers the remaining part of energy $Q^\lambda$ due to the heat conductivity to the wrong side of the whole composite package of the material of the protective suit. And on the wrong side, the temperature, at any moment, should not exceed the standard established by the operating requirements.

The ration of intensity between these two heat flows is inversely proportional to the ratio between the respective thermal resistances, and for their determination, it is basically necessary to solve the adjoint system of equations of non-stationary heat conductivity. Simplifying the task, one can estimate thermal resistance to the energy flow from the flattened drop into the air, but in case of the thermal flow into the protective suit, it will be required to solve a more complicated problem.

Let us consider, again simplifying the task up to the stationary state, heat exchange between the metal drop and the air on the wrong side of the protective suit, divided by a
single partition – the material of the protective suit. Such heat exchange is called heat transfer, and it includes heat abstraction from the drop to the partition, heat transfer in the partition via heat conductivity and heat abstraction from the partition to the colder air adjoining it. On the first and third stages, thermal flows, as per the Newton formula (3), are described by the expression:

\[ \frac{Q}{S \tau_l} = \alpha \Delta \dot{O} \]

(6)

where \( Q \) - thermal flow, \( S \) - the area passed by the thermal flow, \( \tau_l \) - time, \( \alpha \) - heat transfer factor.

On the second stage, the thermal flow can be described by the formula:

\[ \frac{Q}{S \tau_l} = \frac{\lambda}{\ell} \Delta \dot{O} \]

(7)

where \( \lambda \) - coefficient of heat conductivity of the material; \( \ell \) - thickness of the partition (material). Let’s designate \( \alpha_1 \) - heat-transfer factor on the first boundary surface (drop-material), and \( \alpha_2 \) - heat-transfer factor on the second boundary surface (material-air on its wrong side), \( \Delta T_1 \) - difference of the temperatures: drop-external layer of the material, \( \Delta T_2 \) - external layer of the material-layer of the material on the wrong side, \( \Delta T_3 \) - layer of the material on the wrong side -air near the wrong side of the material.

One should note that on both areas of heat transfer, there are temperature jumps, and the total difference of the temperatures \( \Delta T \) is equal to the amount of all differences of the temperatures:

\[ \Delta T = \Delta T_1 + \Delta T_2 + \Delta T_3 \]

(8)

Subject to the fact that the thermal flow on all areas of heat exchange should be still constant, we obtain as follows:
\[
\frac{Q}{S\tau_I} = \alpha_i \Delta \dot{\Omega}_i = \frac{\dot{\lambda}}{\ell} \Delta \dot{\Omega}_2 = \alpha_2 \Delta \dot{\Omega}_2
\]

(9)

It follows that:

\[
\Delta \dot{\Omega} = \frac{Q}{\alpha_1 S \tau_I} + \frac{Q\ell}{\lambda S \tau_I} + \frac{Q}{\alpha_2 S \tau_I} = \frac{Q}{S \tau_I} \left( \frac{1}{\alpha_1} + \frac{1}{\lambda} + \frac{1}{\alpha_2} \right)
\]

(10)

The value opposite to the expression in brackets is referred to as a heat transfer factor \( \hat{\epsilon} \)

\[
\frac{1}{\hat{\epsilon}} = \frac{1}{\alpha_1} + \frac{1}{\alpha_2} + \frac{\ell}{\lambda}
\]

(11)

and the heat transfer process is described by the formula:

\[
\frac{Q}{S \tau_I} = \hat{\epsilon} \Delta \dot{\Omega}
\]

(12)

The value \( \frac{1}{(\kappa S)} \) is thermal resistance, and it increases subject to the thickness of the partition (material). The requirements for the use of protective suits regulate thickness of the fabric, but the value \( \dot{\lambda} \) is not defined by the heat conductivity of fibres, but strongly depends on the structure of fabrics. In addition, the composite package of the material of the protective suits corresponds to several partitions available divided by air space. Besides, subject to the non-stationary state of the process, it is no wonder that in the majority of practical cases, the value \( \dot{K} \) is preferably determined by experience.

Thus, in designing the fire-proof material, one should take into consideration both thermal and physical parameters of damaging factors, and composite packages available.
Approbation of the new designed kinds of fire-proof fabrics from domestic raw material is done at the cloth factory “Kargaly” JSC (Almaty). The methods used for the manufacture of new special protective suits for metallurgists are approved by the garment factory «NIKA» LLP (Almaty). Positive responses for the introduction of new special protective suits are received directly from consumers – metallurgists of DGP VNIITSvetmetmer (Ust-Kamenogorsk).

A fundamental novelty of new fire-proof materials designed during the performance of work, and of devices, and product samples is confirmed with passports for the invention and industrial sample, and also with numerous publications in trade magazines of the Russian Federation (Clothing industry of 2006, 2007).

REFERENCES

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