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Analysis of the effect of heat and corrosion on the mechanical properties of metal structures

E.M. Murtazaev*, E.S. Nabiyev, Sh.A. Berdiyev, Sh.P. Sharipov, A.Q. Karimov, F.X. Boymuratov

Karshi Engineering Economic Institute, 180100, Karshi, Uzbekistan

Abstract. The main content of this article is the reduction of safety problems and risks in civil engineering from the point of view of science in civil engineering. The technology of protecting buildings and structures from corrosion and thermal effects on metal structures requires an increase in the corrosion resistance of structures.

Key words: metal structure, gas corrosion, ferrous metal products, temperature, coatings.

1 Introduction

Decree of the President of the Republic of Uzbekistan dated February 7, 2017 No. PF-4947 "On the Strategy of Actions for Further Development of the Republic of Uzbekistan", No. PQ-2660 dated September 28, 2016 "Rural Development in 2017-2021 on the program for the construction of affordable housing according to updated model projects in localities", PQ-3182 dated August 8, 2017 "Priority measures to ensure rapid socio-economic development of the regions and PQ-3379 dated July 17, 2017 "On measures to ensure the rational use of energy resources" and the production of metal constructions in the implementation of the tasks specified in the regulatory legal documents related to this activity associated time requirements are necessary [1].

Uzbek scientists have also conducted scientific research on the creation of corrosion inhibitors and the study of their inhibition mechanisms. In particular, such scientists as R.S.Tillayev, T.D.Siganov, F.K.Kurbanov, A.T.Djalilov, A.Ikramov, D.Yusupov, Z.B.Tadzhikhodzhayev, H.I.Akbarov, V.P.Guro conducted research in these directions[14-23].

2 Methods

In the construction of industrial buildings, if attention is paid to the use of new efficient building materials, prefabricated elements, the use of light, economical, large-scale, highly factory-made constructions with improved quality, the cost of construction will decrease, metal consumption will decrease, and the durability of the building will increase. the architectural expression is improved. In the design and construction of industrial buildings, special attention should be paid to the solution of environmental problems. Important issues

* Corresponding author: murtazayev_70@mail.ru

such as limiting and stopping the emission of waste into the atmosphere, preventing noise and vibration, electric and magnetic fields, radiation, lighting workplaces, ensuring normal temperature, and air purification should always be in the center of attention.

Depending on the type of technological processes and the related internal mode, character and influence of external weights, as well as other specific features of operation, industrial buildings are in special and often unfavorable conditions compared to civilian buildings. They include: excessive humidity, large amount of heat release (hot shops), aggressive environment, etc.

Even in the recent past, one person, usually an architect, was involved in the design and construction of buildings and structures. As science and technology developed, the size of buildings increased, and the structural solutions and equipment in them became more complex, it became impossible for one person to solve various architectural and engineering issues related to the design and construction of buildings. Currently, teams of qualified specialists, architects-constructors, as well as engineers with various specialties participate in the design and construction of buildings and structures.

The main task of modern construction is to strengthen the production potential of the country based on new techniques and technology. In recent years, great progress has been made in the field of construction in our country as well as in other areas[2, 3, 4, 5].

The quality of the construction product and its creation are mainly formed in three stages:

- design;
- preparation of constructions, products and equipment;
- quality performance of construction and assembly works.

The design of buildings and structures plays a key role in raising the quality of construction skills.

3 Results and Discussion

In connection with the production of metal constructions, as a rule, in factories that are later transported to the construction site, the project should provide for the possibility of transporting them in full or in parts (transportation elements) using appropriate vehicles. It should be designed with attention to the most modern and effective technological methods that ensure the maximum reduction of labor, taking into account the production technology and installation requirements. It should be possible to assemble it in the shortest possible time, taking into account the assembly equipment. Durability of the structure is determined by its physical and mental deterioration conditions. Physical wear of metal structures is mainly related to corrosion processes. Wear and tear is associated with changes in working conditions. Projects, regardless of their goals, should have harmonious forms. This requirement is especially important for public buildings and structures. All these requirements are fulfilled by projects based on the principles developed by science and practice and the main directions of its development.

Requirements for metal constructions When designing metal constructions, the following basic requirements should be taken into account. Satisfaction with the working conditions specified in the design process is the main requirement for design. It mainly determines the system, the structural form of the structure and the choice of material for it[6-10].

Increasing the fire resistance of steel structures of buildings that are dangerous from the point of view of fire (residential and public buildings, warehouses equipped with flammable or combustible materials) is carried out by eliminating direct contact of structures with open flames. For this, ceilings, fire-resistant shells, coatings covered with special compounds are provided. You can significantly increase the fire resistance limit with the help of special coatings in the form of coatings.

The need to save metal is determined by its great need and relatively high price in all sectors (buildings and constructions, transport, etc.). It should be used only in cases where it is not reasonable to replace metal with other types of materials (primarily reinforced concrete) in construction structures.

The disadvantages of steel structures are their tendency to corrosion and relatively low fire resistance. Steel unprotected from contact with moisture, aggressive gases, salts, dust, corrosion. At high temperatures (-600°C for steel, -300°C for aluminum alloys), metal structures lose their load-bearing capacity. With proper design and proper operation, these shortcomings do not jeopardize the performance of the design of its functions, but lead to an increase in initial and operating costs[10-13].

Influence of the deformed state of metals on electrical properties

Electrical resistance is greatly affected by stress-induced distortions. The degree of influence of this factor is determined by the nature of stress.

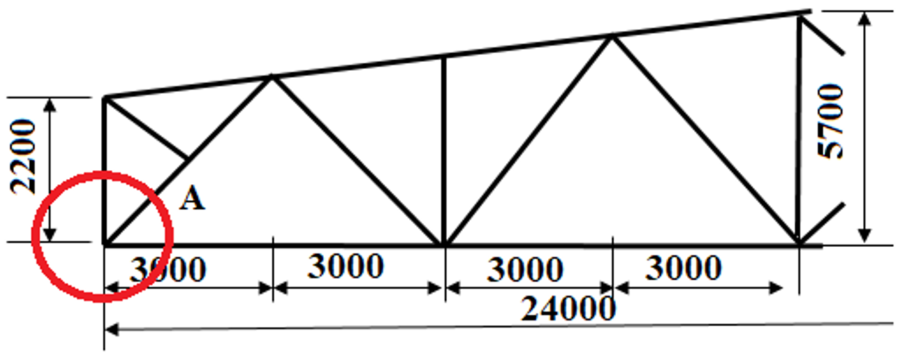

Fig. 1. Metalconstruction

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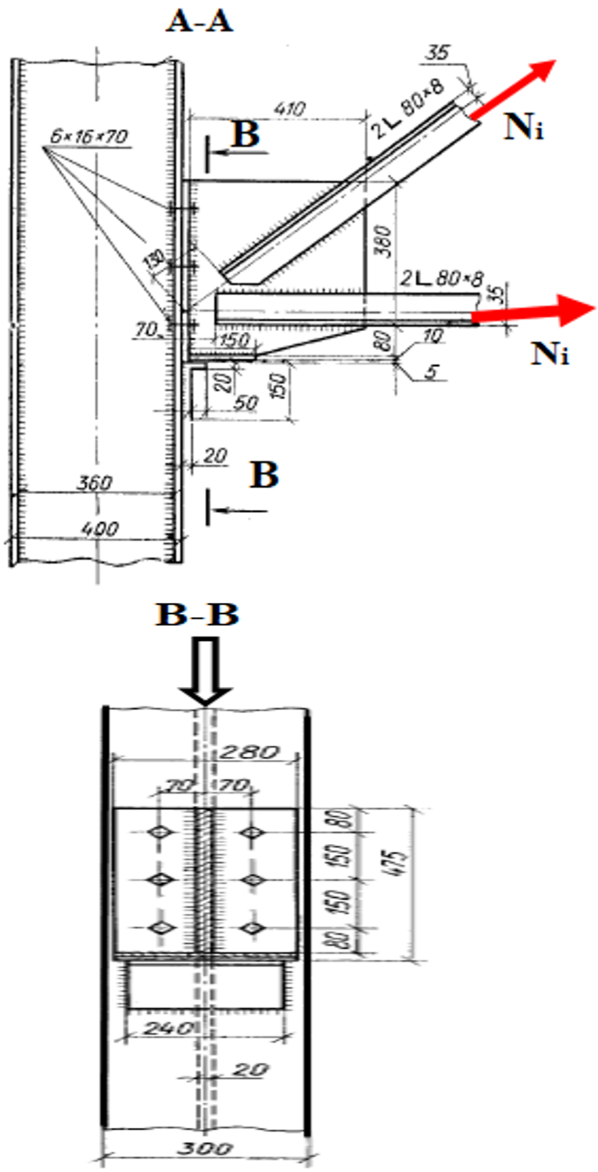

Fig. 2. The resultingforce in a metalstructure

We can determine the force generated in a metal structure by the following formula:

N=$\sum P_{ni} \cdot N_i \cdot \gamma_{pi} \cdot \gamma_n \cdot \Psi$

N_i –force (longitudinal);

$P_{ni} = 1$ theforcegenerated in theelementwhenequalto;

γ_{pi} –loadreliabilitycoefficient;

γ_n –reliability coefficient according to the function of the building;

Ψ –coefficient that takes into account the combined effect of loads.

The load-bearing capacity of a metal structure can be determined depending on its surface and the resistance of the material:

S=$A_n \cdot R_{yn} \cdot \gamma_s$

A_n −element cross-section (netto) surface;

R_{yn} −calculated yield strength of element material;

γ_s − the coefficient that takes into account the working conditions.

The heat resistance of the metal is not great. When the temperature approaches 250^{0}C, the modulus of elasticity of steel begins to decrease, and at 600^{0}C it becomes completely plastic. To meet fire safety requirements, it is necessary to increase the fire resistance of metal structures. Various protection methods can be used for this. [9]

In many metals, the electric resistance decreases as a result of the approximation of atoms and the reduction of the scattering of electrons, which occurs in all-round elastic compression. In this case, the electrical resistance obeys the following relationship:

$\rho_{siq} = \rho_{0(1+\gamma_{com} \cdot p)}$

here, p - is pressure;

γ_{com}=$10^{-5} \div 10^{-6}$pressure coefficient;

ρ_0 – electrical resistance under normal pressure in vacuum.

In combined elastic stretching and twisting, the interatomic distance increases, so this type of deformation leads to an increase in electrical resistance.

When the current is transferred along the deformation vector, the effect of elastic stretching is taken into account by the following formula:

$\rho_{ten} = \rho_{0(1+\alpha_{ten} \cdot \sigma)}$

Here, σ −tensile stress;

α_{ten}-thermal stress coefficient.

Plastic deformation and refinement also increase the electrical resistance of metals and alloys. However, this increase does not exceed 2...6%, even when pure metals are significantly deformed. With a decrease in temperature, the electrical resistance of the refined metal decreases, but does not reach zero at 00K, it takes a certain value called residual resistance.

Annealing leads to an increase in electrical resistance, which is due to internal stresses caused by distortion of the crystal lattice. Softening of refined or tempered metals or alloys reduces electrical resistance.

To meet fire safety requirements, it is necessary to increase the fire resistance of metal structures. Various protection methods can be used for this.

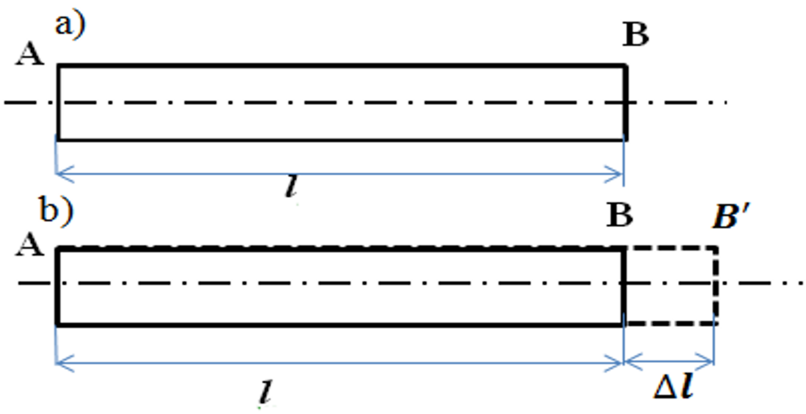

Fig. 3. Temperature change

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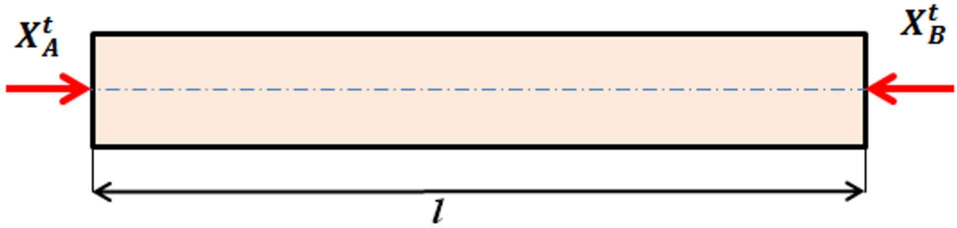
We consider a barge BA with a constant cross-sectional area A and an initial length λ due to temperature changes (Fig. 3). If the temperature of the mast rises by Δt degrees, the mast stretches to a distance of Δl (Fig. 3b). According to the laws of physics, this elongation Δl is directly proportional to the temperature Δt and the initial length l.

$$\Delta l = \alpha(\Delta t) l$$

α- is the coefficient of thermal expansion. Thermal deformation depends on the elongation mentioned above,

$$\Delta l = l\varepsilon_t \, \varepsilon_t = \alpha(\Delta t)$$

In this case, there is no tension in the brush. This can be done by drawing up balance equations using the clipping method



A rod whose length is 1 unit and unit EF is acted upon by a force t0. The static uncertainty of the matter can be seen from the equilibrium equation of statics.

We derive the deformation equation from the condition that the displacement of the steering wheel at the right support is equal to zero

$$\Delta_B = \Delta l_x + \Delta l_t = 0 \text{or, } \Delta_B = \frac{x_A^t \cdot l}{EF} + \alpha l_t = 0$$

α-temperatureexpansioncoefficientofthe material (unitofsize 1/degree),

$$t = t_1 - t_2 \text{fromthis} \frac{\sigma}{E} = \alpha t \text{or}, \sigma = E\alpha t$$

Itcanbeseenthatthetension in thecross-sectionofthe boom does not depend on thelength l ofthe boom cross-section F. Ifthecross-sectionalarea F ofthe boom isknown, thetension in the boom cross-sectioncan also bedetermined.

$$N = \sigma \cdot F = EF\alpha t$$

To meet fire safety requirements, it is necessary to increase the fire resistance of metal structures. Various protective coatings can be used for this.

Increasing the corrosion resistance of steel structures is achieved by introducing special alloy additives into the steel structure, periodically covering the structures with a protective layer in the form of varnishes or paints, as well as by choosing a rational construction form, moisture and dust accumulation. possible).

Metal products used in engineering always work under conditions of high temperature and pressure, strong flows of gases and liquids. Therefore, the issues of protecting metal materials from corrosion are becoming more and more relevant. Corrosion of metals cannot be completely prevented, so the only way to combat it is to find ways to slow it down. The problem of corrosion protection of metals appeared almost at the beginning of their use. Currently, the fight against corrosion is carried out in several directions at the same time - they try to change the environment in which the metal product works, affect the corrosion resistance of the material, and prevent contact between metal and aggressive substances.

In order to calculate the fire resistance of materials based on metal structures, data on thermophysical and mechanical properties of structural elements depending on temperature are obtained. However, to evaluate fire resistance in terms of insulating properties, it is sufficient to use differential equations for thermal conductivity analysis, heat and decay acceptance, and energy and mass conservation in the system.

In order to describe the properties of the fire-resistant coating, it was proposed to use a mathematical model to increase the fire resistance of E-44-1 brand coatings based on fire-resistant epoxy resins containing metal by forming a coating on the surface of the metal structure. Temperature rise diagram of fire-protective corrugated coatings (Fig.4)

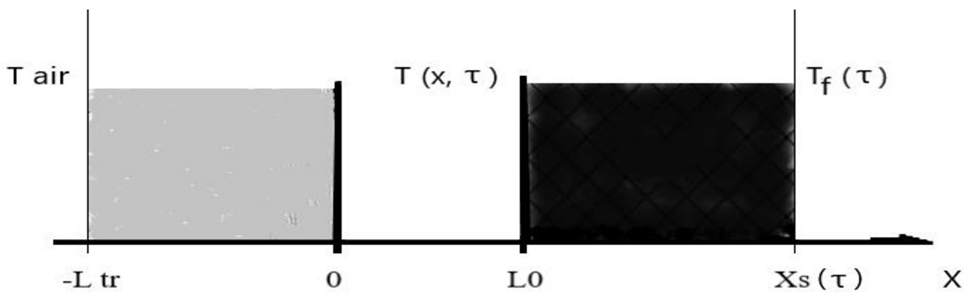


Fig. 4. Temperature rise diagram of fire-resistant intumescent coatings.

The model is based on treating the coating material as a mixture of simple substances that can form components in the gas phase when heated. As a result of the formation of gaseous components in the temperature range that affects the properties of the coating, it leads to the appearance of convexity.

This study makes several additional simplifications:

1) coating includes four components - one chemically inert (n) and one active component (a), when heated endothermic inert components condense (c) and turn into gaseous components (g);

2) the bulging coating does not affect the structure of components in the gas phase, therefore, effects related to mass loss are not taken into account in the experiment;

3) materials with a fire-protective foamable polymer composition are close to chemically inert substances.

According to experience, the spatial state can be considered one-dimensional. The basic spatial coordinate (x) oriented towards the normal protected surface is measured from the distance between the cellulosic material and the protective coating towards the coating.

1) $-L_{tr} < x < 0$ – a substrate containing a protected metal structure;

2) $0 < x < x_s$ – fireproof protective cover.

The thermal conductivity of the material based on the metal structure is expressed by the differential equation of thermal conductivity:

$$\frac{\partial T(x,\tau)}{\partial \tau} = \frac{\lambda}{c_p \cdot \rho} \cdot \frac{\partial^2 T}{\partial x^2} \tag{1}$$

where: c_p - isobaric heat capacity of material based on metal structure, J/(m^3·K); λ - thermal conductivity of metal material, W/(m·K);

The air boundary of the material based on the metal structure (2) has the form of the equation:

$$-\lambda_{tr} \cdot \left.\frac{\partial T(x,\tau)}{\partial \tau}\right|_{-L_{tr}} = \alpha\left(T(-L_{tr})\right)\cdot\left[T_{air} - T(-L_{tr})\right] \quad (2)$$

where: L_{tr}- is the thickness of metal-based material, mm; T_{air} - air temperature, K; α - heat transfer coefficient of a certain surface, W/(m·K);

$$\alpha = \frac{\lambda}{c_p \cdot \rho} \quad (3)$$

T_f– average (flame) temperature, K; L_0 – initial coating thickness, mm.

The differential equation of thermal conductivity of the material is expressed as follows:

$$c_p \cdot \rho \frac{\partial T(x,\tau)}{\partial \tau} = \lambda \frac{\partial^2 T}{\partial x^2} \quad (4)$$

Numerical solutions were given for the initial thickness L_0=0.2÷0.3 mm, flame temperature t_f=850÷900°C, and thickness of metal-containing material L_{tr}=3 mm. As a result, the time dependence of coating temperature, convexity coefficient, heat transfer coefficient and the percentage of active components was determined and analyzed. The dependences on the obtained mathematical model were adapted to the experiments by changing the free parameters.

4 Conclusion

Measuring the thermal conductivity of samples of non-irradiated and irradiated polymer coatings with different numbers of neutrons for fire-protection intumescent polymer composite coatings using the dynamic calorimeter method in the IT-λ -400 equipment, in the temperature range from 10°C to 150°C. Went the error of measuring the heat transfer coefficient of the samples did not exceed 10%. The results and analyzes of experimental tests on the thermal conductivity of the proposed flexible polymer composite coatings were presented and their efficiency was studied. In the course of scientific research, E-21-1, E-21-2, E-21-3 and E-21-4 brand fire protective convex coatings based on acrylic copolymers and E-44-1, E-44-1 based on epoxy resin were produced. 44-2, E-44-3, and E-44-4 fire protective foam coatings, temperature dependence of the thermal conductivity coefficient and temperature dependence of the samples of acrylic copolymers and epoxy resins before forming composites was studied. Taking into account the high contribution of scientific research to the development of the above-mentioned technologies, it was aimed to propose the study and production of the properties of fire-protective flexible polymer composite coatings based on acrylic copolymers and epoxy resin.

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