Evaluation of aging phenomena of unalloyed weldable steel from electric steelwork TMK - Reşiţa

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Keywords

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1. Characteristics of steel buildings for steelworks

Steelwork hall is a "heavy hall" part of the metallic halls from the steel industry due to: large-scale technological process, the geometric dimensions of the hall, very hard working regime of the crane and their high capacity, their constructive form, static scheme chosen, etc.

Electric steelworks hall analyzed has the static scheme with two openings, ruler across the frame being made as lattice beam form for each opening. It was designed and built in the fourth decade of the last century, being considered for that period, one of the reference works in Romanian, because she "dressed" the old steelworks hall, demolished at the end of construction. By this solution, the stationing time was minimized during the demolition of the old halls and it was executed repairs to the steel furnaces.

The normal operation of the hall (40 years) is exceeded, the introduction of modern technological processes requires the development of technical documentation to assess current safety and intervention works (building/ consolidation). The current rules, national and European, are referred to safety structures to other materials (masonry, concrete, etc.), but for the metals, there are insufficient rules, with general references to the values of calculation, which characterizes the strength and rigidity (resistance calculations, bearing capacity, elasticity modulus, etc.).

In paper [1] for metal structures are set the values: resistance calculation of consolidated elements, modulus (depending on the application and the length element), and the coefficient of reduction for limit states.

Compared with the metal structure in other industries, the metal structures from siderurgy present some untreated peculiarities, current standards of design, operation, maintenance and tracking. Among them, the metal structures for steelworks represents the most solicited halls, the main features of these are:

a) increased operating regime from that taken into account in the original design, due in particular:

- Load levels much higher than the estimated standards such as crane loads for which it was proved that the dynamic coefficients are more than that prescribed by rules;
- The actions character resulting from the technological processes. Thus, for many elements considered being static loaded, the real character of the action is quasidynamic or dynamic (for example, in the immediately period following the introduction of the electrodes in the furnace, the metallic roof structure is subjected to vibration). In different periods of the technological process results dynamic actions and shocks difficult to quantify which affect the safety components, the metallic structure resistance, some generated by the emergence of the defects and damage to the technological equipment (especially in cranes);

b) technological temperature with high values, often exceeding the values established by the regulations. With higher values, there is a decreasing of the calculation resistance values and modulus (around 300^{o}C, the steel resistance is reduced by half and at higher values than 500...600^{o}C, the bearing capacity of the steel decreases practically to zero);

c) Changeling the technological process (through increased compared to the original) with high lifting capacity and the emergence of other load distributions than the original. These changes in the technological process, imposed by the changes in technology, in most cases, lead to increased demand for strength components of the steel structure;

d) the permanent presence of the corrosion process as a result of the technological processes which results in a wide range of gases, creating a highly aggressive environment and, under the influence of atmospheric humidity, leads to semi-wet atmospheric corrosion phenomenon and, rarely, generalized corrosion. The corrosion speed process in the atmosphere of the steelworks halls is determined by relative humidity (the main factor, the critical value, being 70%), nature and quantity of gas present in the atmosphere and dissolved in a film of moisture, dust particles, the ambient temperature chemical composition of the steel, etc.;

e) Industrial dust deposits, resulting from the technological process, especially in the period when were no special capture and collection equipments. Very large amount of industrial dust loading (which exceeds the maximum values stipulated) due to lack of work to get away from the roof, have led to important efforts in the metallic elements of the roof, being one of the reasons that caused the appearance structural accidents;

f) the high functioning time (40 years) until it was received funds to repairing and consolidation. Between these periods there was a low concern about the behavior on long periods of the resistance structures of halls steelwork due to lack of specialized personnel and long stationary intervals and inactivity in this domain (lately).

It can be concluded that siderurgy, through many and various technological processes, involving much greater demands by the effect of increased atmospheric corrosion, increase production capacity, technology and temperature variation of heavy duty and very difficult operation, for metallic structures resistance, which in some technologically advanced countries, there are specific rules for design, operation and maintenance.

2. Safety metal structure

Safety steelworks steel structures resistance must be considered in accordance with the current rules in the limit states method by analyzing, for each component and structure, in general, the relationship:

$$E_{d,dst} \leq E_{d,st} \quad (1)$$

where $E_{d,dst}$ and $E_{d,st}$ are the calculus effects of the destabilized and stabilized actions.

It will consider:

a) limit states (reaching condition involving loss of ability to satisfy the conditions of exploitation related to the established destination or emergence of life and human health hazards, respectively for material goods and cultural, which conservation depends on the respectively building). Limit states to be analyzed are:

a.1) ultimate limit state which corresponds to bearing exhaustion capacity or other irreversible loss of quality construction to the operation (which corresponds to tensile strength, stability and fatigue limit state) and consists of checking the relation (2), obtained by customizing the relationship (1) as:

$$S_d \leq R_d \quad (2)$$

where S_d is the maximum computing solicitation and R_d the resistance capacity of element. The relationship to check the joining (with rods or welding) of components of resistance structure is:

$$P_{calcul} \leq P_{lim}^{min} \quad (3)$$

where P_{calcul} represents the maximum calculated effort which act on the joining element (screw, weld), and P_{lim}^{min} the minimum effort which can be supported by the joining element.

a.2) The state limit of normal operation, according to Romanian norms, or service limit state, according to European standards, which corresponds to interruption of capacity to ensure a normal operation. In paper [2] it is showed that this relationship consists in verification of the relations:

$$\lambda_{max} \leq \lambda_a \quad (4)$$

$$f_{max} \leq f_a \quad (5)$$

For axial solicited elements and bending solicited where λ_{max} and f_{max} is the maximum slender coefficient allowed and the arrow allowed (depending on destination and the important elements), for the whole metal structure (transversal and longitudinal separately) the verification relation is:

$$F_{max,str} \leq F_{a,str} \quad (6)$$

where $F_{max,str}$ and $F_{a,str}$ is the maximum movement of the whole structure, namely the admitted.

b) structure assurance (involving a solution to limiting the probability of achieving the desired values and overcome the various states limit).

The main factors for the safety assessment of metal structure are:

- Conception (by the mode how were respected the design and calculation rules);
- Manufacturing, machining and assembly (in accordance with the technical regulations for that period);
- Construction operation (in accordance with the design conditions);
- Construction evaluation (according to the design norms and the regulations);
- Regularly maintenance (by consulting Annex D of the Book Building, where are highlighted the repair works, consolidations, etc. during the operation hall).

For safety assurance of the metallic structures the main factors which must be analyzed are:

- Element importance;
- Solicitation level;
- Age of the element;
- Aggressive nature of the environment

By some reduction coefficients, β and α for each limit state analyzed, presented in the paper [1], so that relations (2)...(6) will become:

$$S_d \leq \beta R_d \quad (7)$$

$$P_{calcul} \leq \beta P_{lim}^{min} \quad (8)$$

$$\lambda_{max} \leq \alpha \lambda_a \quad (9)$$

$$f_{max} \leq \alpha f_a \quad (10)$$

$$F_{max,str} \leq \alpha F_{a,str} \quad (11)$$

The particularities for the structure resistance of the metal halls of metallurgy steelworks presented the first paper, have the effect of reducing toughness steel (tensile property to store the tensions), so the breaking has not a plastic character or tenacious nature (characterized by noticeable deformations). It is necessary to evaluate the actual behavior of the steel structure components by performing:

a) Physical and mechanical tests on:

a.1) tensile testing for evidence the following:

- Yield strength ($R_{p0,2}$);
- Tensile strength (R_m)
- Specific elongation (A_5);
- Reduction area (Z);

a.2) tests for toughness steel determination, using Charpy specimens with U and V notch at ± 20°C and 0°C temperatures.

a.3) bend testing;

b) Determination of chemical composition of the steel mark

For global-plastic analysis, which is best suited to the calculation of steel structures, the steel grades must meet the following conditions:

- the ratio between tensile strength (R_m) and
- Yield Strength ($R_{p0,2}$) to be greater than or equal to 1.2

Because the most consolidation works are performed by welding, it is recommended and the metallurgical behavior verification and of the steel mark.

3. Evaluation of current behavior of steel mark

Determination of the technical condition of the roof steel structure by modernization of the steelworks of the capture gases axis 17 ... 19, by the work intervention on the steel structure in the subjected modernization area involves evaluating of the current behavior of steel mark by:

- Determining of resistance calculation (comparison)
- Physical and mechanical tests
- Chemical composition determination,
- Aging estimation and steel toughness

For this it were assayed 6 samples from the superior and inferior dormer from the axis 17, 18 and 4 according with the sample assaying plan (figure 1). Because of the age about 60 years by evaluating the current quality of the composition of the materials from the roof structure it can be established the mechanical and structural degradation degree compared with the structural and mechanical characteristics related to the technical standards required for steel alloyed used.

The assessment of the aging phenomena will characterize the shock bending resistance and the setting of the brittle fracture risk.

Aging phenomena are typical to metallic materials which have undergone hot plastic deformation and subsequent action of the temperatures. It largely affects the plastic deformation capacity of the materials, reducing the reliability of properly welded or seamless steel structures of great importance.

Evaluation of the aging phenomena tendencies is based on several criteria, including the characteristics of dynamic toughness (shock).

The aging susceptibility of OL37-2n steel (aging degree) is determined by bend testing at 20°C and comparing the toughness characteristics (fracture energy KV is chosen) determined with those from the current state (CS).

In determining the breaking energy after artificial aging (AA) is using resilient specimens of 11×11 mm section subject to:

- Cold plastic deformation by compression with the compression level of 7%;
- Warming at 250°C, maintaining to this temperature for one hour followed by a slow cooling in air.

The degree of aging ΔIA is calculated with the relation:

$$\Delta IA = \frac{KV_{CS} - KV_{AA}}{KV_{CS}} 100 \text{ [\%]} \qquad (12)$$

Where

- KV_{CS} is the average rupture energy KV of the steel the current state (CS)
- KV_{AA} is the KV average fracture energy value of the steel in artificial aging state (AA)

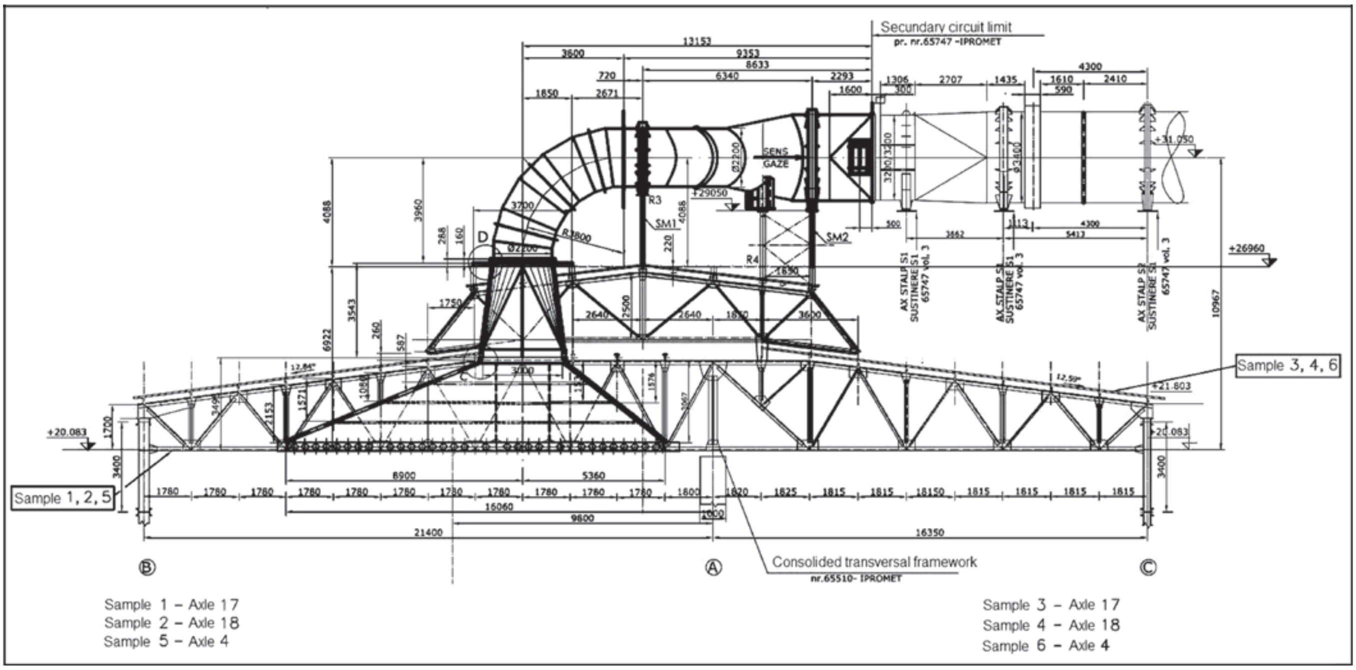

Figure 1. Sample assaying plan

It is considered that if $\Delta IA \geq 50\%$, the steel presents a high sensitivity to aging phenomena.

The aging degree (ΔIA) can involve the steel degradation phenomenon. The degradation ability of non-alloyed steel is the higher with the greater value of ΔIA estimator [4].

Table 1. KV Fracture energy values obtained in AA state

Sample	Longitudinal direction (L) Fracture energy KV [J]		Transversal direction (T) Fracture energy KV [J]	
	State CS	State AA	State CS	State AA
1	36.3	8.66	21.3	6.0
2	38.6	6.6	20.6	6.0
3	60.6	8.6	24.6	7.6
4	75.0	9.0	28.6	7.6
5	45.6	7.0	18.3	5.6
6	67.6	11.6	23.0	7.6

Table 1 presents the KV fracture energy values obtained in AA state, while Table 2 contains the calculated ΔIA estimator values calculated with relation (2).

In Figure 2 is presented ΔIA estimator variation on the analyzed samples.

Table 2. Calculated values of ΔIA estimator

Sample	ΔIA estimator [%]	
	L direction	T direction
1	76.30	71.83
2	82.90	70.87
3	85.82	69.10
4	88.00	73.42
5	84.64	69.39
6	82.84	66.95

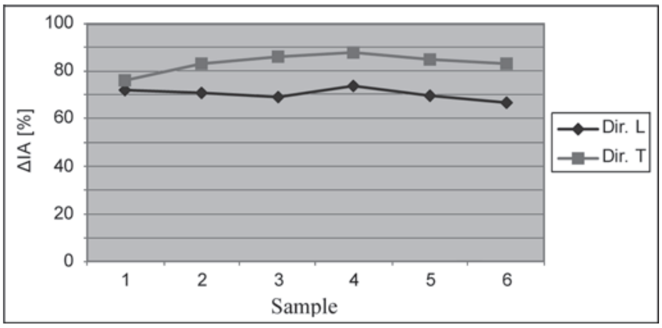

Figure 2. ΔIA = f(sample) variation

On both directions analyzed (L and T) is observed that ΔIA estimator has high values of max. 88% on "L" direction and 73.42% on "T" direction the analyzed steel presents a high sensitivity to aging phenomena.

4. Conclusions

4.1. The values of the reduction coefficients β= 0.778 and α = 0.92 and the resistance calculation (comparison) taking into account the spatial working of the structure of 0.90 R_m, respectively 0.90 $Rp_{0,2}$ which in the Expertise Structural was determined the actual safety level and were established the consolidation works

4.2. There are necessary to establish special tracking of the resistance structure of the hall steelworks;

4.3. Warning criterion reaching as a result of steel toughness reducing of the current mark, high sensitivity to aging, exceeding the normal operating period of the hall without the execution of repairs works and strengthening,

4.4. The necessity of Structural Expertise realization on the entire hall wills to be analyzed the current safety degree for all steel structure components of resistance and possible strengthening works;

4.5. Behavior evaluation of current the steel structure components, structure resistance basing on the technical documentation (studies) developed by the staff and authorized companies;

4.6. Sensitivity to steel aging is high; the aging degree presents high values, between 66.95 and 88.0%, well above 50%, so the risk of brittle-type fracture of the steel is high.

4.7. At the completion of normal operating period for the halls from metallurgy are necessary intervention (Reconditioning) works to restore them an adequate level of safety;

4.8. The need to develop specific rules for existing steelworks buildings, especially in metallurgy, to assess the current performance and proper maintenance activities designed to help increase their reliability.

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