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ESTABLISHING EQUATIONS FOR CALCULATING THE CHANGE OF LOWER YIELD POINT DEPENDING ON THE TIME OF CORROSION EFFECT

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Abstract

In this paper, equations are established to predict how the values of the lower yield point in the stress-strain curve depending on a time of corrosion influence will change. Although this point is of theoretical importance in the theory of strength of materials, its change in corroded steel is of practical importance, since this point determines according to the theory which minimum load or stress is required to maintain the plastic behavior of material. A well-founded mathematical principle was used to process experimentally obtained data in two main directions - the stochastic method and the average method. Diagrams of the variation of values in corroded steel were drawn up and equations of the 9th degree were established using polynomial approximation.

Keywords: Corrosion, Equations, Establishing, Lower Yield Point, Time,

I. Introduction

Using the definition of the strength of materials, the lower yield point is a point at which minimum load or stress is required to maintain the plastic behavior of material such as points [XII], and [XIX]. This point is essential because it determines the lowest point of the load at which irreversible plastic deformations remain. On the other hand, it is in the yield strength zone and the very presence determines at what minimum stiffness of the load the plastic deformations are irreversible. It is known [II-VII] that corrosion leads to a negative impact on mechanical properties, geometric characteristics of the cross-section, surface defects, structural changes, etc. Steel is used in construction and has a polycrystalline structure. This means that a given volume of this metal contains a large number of small crystals that have a corresponding orientation. The atoms of the steel are arranged in a certain way in the crystal lattice to build up the private spatial orientation. These things depend on the type of steel as well as the conditions of crystallization. In this crystal lattice, there are forces of interaction between the atoms. They form a system that is completely defined and characteristic of each metal. As corrosion begins to act, it will change the structure of these crystals [V-VII] as a result of which will start displacements of the atoms and at the same time the interaction forces that depend on the displacements will change. This dependence is complex, but for small values, we can assume with sufficient accuracy that they will be linear. This linear relationship, manifested for multiple randomly oriented crystal lattices in corroded steel, leads gap at the values at which the lower yield point is defined This necessitates the conclusion that the lower yield point will change depending on the degree of corrosion of the steel. The change of this point also determines the rocks in which there will be residual deformations [IV-VI] [XIII]. To predict the change of values at which this point can be determined, one should collect enough experimental data to be processed by a mathematical model for prediction, and so, it will be possible to draw up empirical equations [VIII-X] that can be used to describe the process of changing depending on from the corrosion category.

II. Mathematical model for establishing equations

The use of a certain type of mathematical model to establish equations requires combining two mathematical directions - probability theory and mathematical statistics [XV], [XVII], [XIV], [XIII]. Probability theory studies the theoretical characteristics of random events and their relationships, while mathematical statistics deals with the processing of the results of experimental research, also known as the empirical part of the mathematical model. From here it follows that for a given data distribution, a theoretical distribution of the function that describes the data can be constructed. Most often, these are obtained experimental data of the studied quantity X, as a result of which a series of values X1, X1…….Xn so-called was obtained. variation order. Values are grouped in an interval ΔX most often of the same size. The most accurate results are obtained when this interval ΔX is small and thus the change of the experimentally obtained curve is tracked. Average relative frequency is calculated according to the formula [XVI], [XVIII]:

$$\bar{n}_1 = \frac{n_i}{\Delta X.n} \tag{1}$$

Where: n_i- the number of cases in i interval; n - total number of cases;

The numerical value of $\bar{n}_1$ is applied along ordinates (y-axis) and thus obtains the histogram. As a result, we get the empirical probability density curve, or so-called histogram [XVI], [XVIII]. It corresponds to the theoretical probability curve enclosed by a stepped area. Instead of a histogram, an empirical polygon can be drawn, the vertices of which can be averaged over the intervals, thus we get the empirical distribution curve (cumulative curve) As each ordinate is equal to the areas corresponding to the corresponding part of the histogram. Based on the data from the variation series, we can calculate the main numerical characteristics of the empirical distribution (function) - arithmetic mean value, standard deviation, coefficient of variation (variability) [XV], [XVII], [XIV], [XIII]. The mathematical procedure is known as Kolmogorov's criterion. Fulfillment of this criterion results in continuity of functions and uniform data processing intervals. In the basic conception of polynomial approximation theory and methods, we can represent each dependence as a polynomial of the corresponding degree. The polynomial in f (x) is a function of the probability curve [VIII-X]

$$f(x) = a_0 + a_1.x + a_2.x^2 + a_3.x^3 + a_4.x^4 + a_5.x^5 \dots\dots\dots\dots.. + a_n.x^n \quad (2)$$

Where: $a_{0,}\ a_1,\ a_{2,} \dots..a_n$ - coefficients of the function to be established

If we look at cases in which, instead of knowing function expression, we have point values [VIII-X]. It is enough to find a polynomial that passes through these points, and we want the polynomial to pass through the given data, i.e., interpolating polynomials [VIII-X]. Let us assume that we know (or choose to try) the function f (x) exactly at several points and that we want to approximate the behavior of the function between these points [VIII-X], [XX], [XVI], [XVIII]. In its simplest form, this is equivalent to linear assembly (Fig. 2.1), but it is often more accurate to look for a curve that has no "angles" in it (Fig. 2.2) [VIII-X].

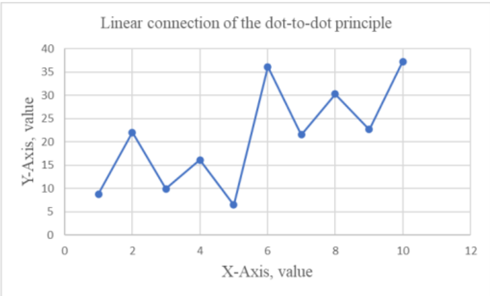


Fig: 2.1. Graph of linear connection

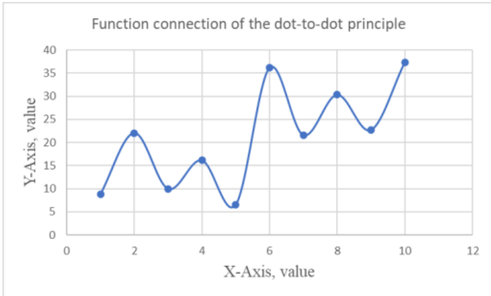


Fig: 2.2. Graph of function connection

In the first case (fig. 2.1) we have a linear connection of the dot-to-dot principle, which means that the function between two points is linear and exactly at the point it will break, since the first derivative will be equal to zero, i.e. the function will not be continuous. In the second case (fig. 2.2) dot-to-dot connection by function (no "angles") and a polynomial function is obtained and the first derivative of this function will not be zero, which automatically fulfills the requirement mentioned above for the continuity of the function and the Kolmogorov agreement criterion. There are many experimental data [II] from which numerical values can be taken, and processed by the already described mathematical model (stochastic method and average method), the corresponding values are established as points in a histogram, then with the help of connecting and the dependence equation was established. Having a continuous function, its equation is established with the help of polynomial approximation.

III. Establishing of equations

Using the mathematical model described in the previous point, taking into account for the availability of a large amount of published experimental results, after being processed by the stochastic method and the arithmetic mean method, a graph of the function is drawn. Using the polynomial approximation of the principal dot-to-dot connection by function (no "angles"), the equation for change of lower yield point depending on the time of corrosion effect is established as a function of time, i.e. ε (t) and σ (t), where t is a time in months on corrosion impact according to a corrosion category. This method has also been applied in other research papers [VIII-X].

Corrosion category C1

The corrosion category does not occur in natural climatic conditions but is intended for indoor climatic conditions in buildings according to the ISO 12944-5 standard, such as heated production buildings, offices, shops, schools, hotels, etc. Table 1 presents a result after processing by stochastic method and average method. In fig. 3.1 shows the relationship between the change in relative strain versus the action time of the corrosion category, and Fig. 3.2 shows the relationship between the change in strength over time due to the corrosion effect of the category.

Table 1: Results after processing for the C1 category

time, [months]	Strain of lower yield point, ε, [mm]		Stress of lower yield point, σ, [MPa]	
	Stochastic method	Average method	Stochastic method	Average method
0	8.76	8.95	359.19	363.43
9138	9.034	8.366	343.7	347.4
14769	9.939	9.836	365.9	366.4
24923	9.12	9.174	376.9	405.3
34892	5.49	5.008	352.9	357.9
46154	6.125	5.569	358.6	372.9
54000	5.554	5.339	379.9	369.8
64615	5.295	4.173	316.1	345.5
73108	2.654	2.399	295.7	377.9
77262	2.274	2.132	339.4	363.9

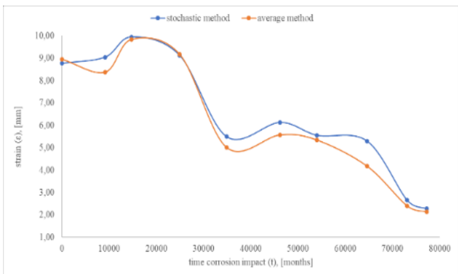


Fig: 3.1. Variation of the strain

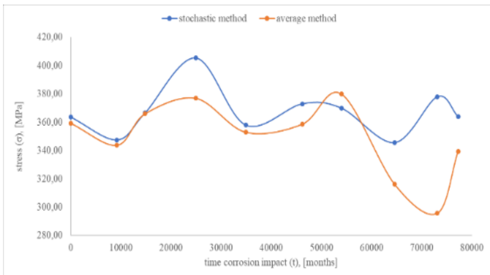


Fig: 3.2. Change in stress

Using the polynomial approximation [VIII-X] from fig. 3.1 and fig. 3.2, functional dependence for the strain and stress point in dependence of the time of the influence of the corrosion (in months) is established in equations (eq.3, eq.4, eq.5, and eq.6).

Stochastic results

- Strain equation

$$\varepsilon(t) = 1.2221947488597604.10^{-39} t^9 - 4.3618005717389456.10^{-34} t^8 + 6.5152802381158109.10^{-29} t^7 - 5.2743960539528150.10^{-24} t^6 + 2.5016421567173534.10^{-19} t^5 - 7.0066811630307258.10^{-15} t^4 + 1.10906343169073.10^{-10} t^3 - 8.9136486812506345.10^{-7} t^2 + 2.81677537592712.10^{-3} t + 8.76 \quad (3)$$

- Stress equation

$$\sigma(t) = 1.4500926187755664.10^{-38} t^9 - 5.5563622055581102.10^{-33} t^8 + 8.903866838148908.10^{-28} t^7 - 7.728705179122.10^{-23} t^6 + 3.9301461814306737.10^{-18} t^5 + 1.1802252337806010.10^{-13} t^4 + 1.997957823792752.10^{-9} t^3 - 1.68699507413.10^{-5} t^2 + 5.265601380819774.10^{-2} t + 363.43 \quad (4)$$

Average results

- Strain equation

$$\varepsilon(t) = 9.7091351584243211.10^{-40} t^9 - 3.5196011724319663.10^{-34} t^8 + 5.3348153766902498.10^{-29} t^7 - 4.3718331927727373.10^{-24} t^6 + 2.08882125254589.10^{-19} t^5 - 5.838761504302115.10^{-15} t^4 + 9.05832216749112.10^{-11} t^3 - 6.885552479570321.10^{-7} t^2 + 1.91224636951636.10^{-3} t + 8.95 \quad (5)$$

- Stress equation

$$\sigma(t) = -7.4876168600727451.10^{-39} t^9 + 2.476717672902705.10^{-33} t^8 - 3.386725205502527.10^{-28} t^7 + 2.4943381434116747.10^{-23} t^6 - 1.0873876178611213.10^{-18} t^5 + 2.9294684401192641.10^{-14} t^4 - 4.94790122732.10^{-9} t^3 - 4.9588158146999.10^{-6} t^2 + 2.1868487411309.10^{-2} t + 359.19 \quad (6)$$

Corrosion category C2

According to ISO 12944-5, corrosion category C2 is for environments with low pollution levels, such as agricultural areas. Unheated buildings where condensation can occur, such as warehouses, depots, sports facilities, and others. In fig. 3.3 shows the relationship between the change in relative strain versus the action time of the corrosion category, and Fig. 3.4 shows the relationship between the change in strength over time due to the corrosion effect of the category. Table 2 presents a result after processing by stochastic method and average method.

Table 2: Results after processing for C2 category

time, [months]	Strain of lower yield point, ε, [mm]		Stress of lower yield point, σ, [MPa]	
	Stochastic method	Average method	Stochastic method	Average method
0	8.76	8.95	359.19	363.43
475	9.034	8.366	343.7	347.4
768	9.939	9.836	365.9	366.4
1296	9.12	9.174	376.9	405.3
1814	5.49	5.008	352.9	357.9
2400	6.125	5.569	358.6	372.9
2808	5.554	5.339	379.9	369.8
3360	5.295	4.173	316.1	345.5
3802	2.654	2.399	295.7	377.9
4018	2.274	2.132	339.4	363.9

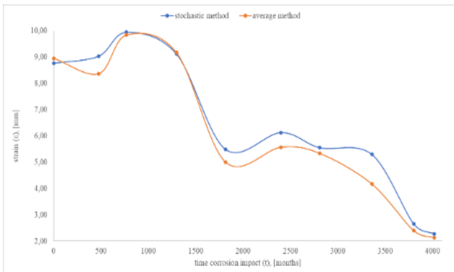


Fig: 3.3. Variation of the strain

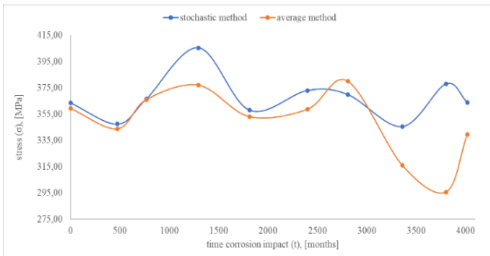


Fig: 3.4. Change in stress

Using the polynomial approximation [VIII-X] from fig. 3.3 and fig. 3.4, functional dependence for the strain and stress point in dependence of the time of the influence of the corrosion (in months) is established in equations (eq.7, eq.8, eq.9, and eq.10).

Stochastic results

- Strain equation

$$\varepsilon(t) = -2.8230227697067165.10^{-27}\, t^9 + 4.9485232638877778.10^{-23}\, t^8 - 3.604843703728745.10^{-19}\, t^7 + 1.4233566079976179.10^{-15}\, t^6 - 3.3461018547245801.10^{-12}\, t^5 + 4.8631947476896104.10^{-9}\, t^4 - 4.369525303617237.10^{-6}\, t^3 + 2.260301892656886.10^{-3}\, t^2 - 5.083047923479528.10^{-1}\, t + 8.76 \qquad (7)$$

- Stress equation

$$\sigma(t) = 5.2201584797068064.10^{-27}\, t^9 - 1.040049268666033.10^{-22}\, t^8 + 8.6660250499868647.10^{-19}\, t^7 - 3.9113602790672632.10^{-15}\, t^6 + 1.0342147835625786.10^{-11}\, t^5 - 1.6149094939113927.10^{-8}\, t^4 + 1.421510327862.10^{-5}\, t^3 - 6.2410116668287219.10^{-3}\, t^2 + 1.0128744212189265\, t + 363.43 \qquad (8)$$

Average results

- Strain equation

ε (t) = 3.4933408099557733.10^{-28} t^9 - 6.5854165383786699.10^{-24} t^8 + 5.1908280704223837.10^{-20} t^7 - 2.2121100546254318.10^{-16} t^6 + 5.4962904984619833.10^{-13} t^5 - 7.989429035025869.10^{-10} t^4 + 6.445773356288.10^{-7} t^3 - 2.54807650719059.10^{-4} t^2 + 3.680366357391.10^{-2} t + 8.95 (9)

- Stress equation

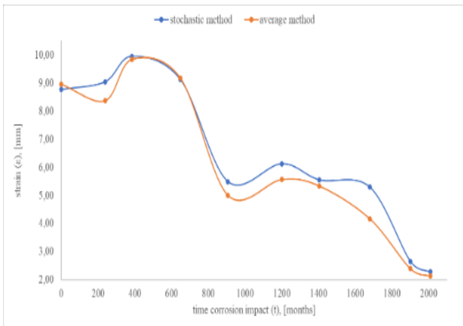
σ (t) = -2.6868797049072329.10^{-27} t^9 + 4.620688312862356.10^{-23} t^8 - 3.284790643361487.10^{-19} t^7 + 1.2576228738899837.10^{-15} t^6 - 2.8498851435480047.10^{-12} t^5 + 3.991205442624378.10^{-9} t^4 - 3.5052826574178.10^{-6} t^3 + 1.8274650973704361.10^{-3} t^2 - 4.1932628867208827 t + 359.19 (10)

Corrosion category C3

It exists in urban and industrial regions with moderate sulfur dioxide pollution and coastal areas with low salinity. In the indoor area of a building, it is available in the production part with high humidity and air pollution, such as industrial plants, laundry rooms, breweries, food production rooms, etc., according to ISO 12944-5 standard. In fig. 3.5 shows the relationship between the change in relative strain versus the action time of the corrosion category, and fig. 3.6 shows the relationship between the change in strength over time due to the corrosion effect of the category. Table 3 presents a result after processing by stochastic method and average method.

Table 3: Results after processing for the C3 category

time, [months]	Strain of lower yield point, ε, [mm]		Stress of lower yield point, σ, [MPa]	
	Stochastic method	Average method	Stochastic method	Average method
0	8.76	8.95	359.19	363.43
238	9.034	8.366	343.7	347.4
384	9.939	9.836	365.9	366.4
648	9.12	9.174	376.9	405.3
907	5.49	5.008	352.9	357.9
1200	6.125	5.569	358.6	372.9
1404	5.554	5.339	379.9	369.8
1680	5.295	4.173	316.1	345.5
1901	2.654	2.399	295.7	377.9
2009	2.274	2.132	339.4	363.9



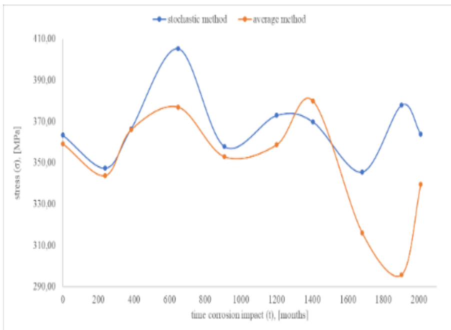


Fig: 3.5. Variation of the strain

Fig: 3.6. Change in stress

Using the polynomial approximation [VIII-X] from fig. 3.5 and fig.3.6, functional dependence for the strain and stress point in dependence of the time of the influence of the corrosion (in months) is established in equations (eq.11, eq.12, eq.13, and eq.14).

Stochastic results

- Strain equation

$$\varepsilon(t) = 2.2515583478988664.10^{-25}\, t^9 - 2.08939759348609.10^{-21}\, t^8 + 8.1152392267349876.10^{-18}\, t^7 - 1.7082665478963731.10^{-14}\, t^6 + 2.1068180710754758.10^{-11}\, t^5 - 1.5344135487768963.10^{-8}\, t^4 + 6.315876965787.10^{-6}\, t^3 - 1.3201257889947451.10^{-3}\, t^2 + 1.0850319756056787.10^{-1}\, t + 8.76 \quad (11)$$

- Stress equation

$$\sigma(t) = 2.6758181837436075.10^{-24}\, t^9 - 2.665566337610248.10^{-20}\, t^8 + 1.110517087510115.10^{-16}\, t^7 - 2.5061812163330238.10^{-13}\, t^6 + 3.31351475554.10^{-10}\, t^5 - 2.5872753948088745.10^{-7}\, t^4 + 1.138941126643777.10^{-5}\, t^3 - 2.5011687045203779.10^{-2}\, t^2 + 2.0311564834830795\, t + 363.43 \quad (12)$$

Average results

- Strain equation

$$\varepsilon(t) = 1.7892287499104568.10^{-25}\, t^9 - 1.686456365998769.10^{-21}\, t^8 + 6.6465397782329438.10^{-18}\, t^7 - 1.416228478343965.10^{-14}\, t^6 + 1.759401927621207.10^{-11}\, t^5 - 1.2787397935997077.10^{-8}\, t^4 + 5.1584192432644.10^{-6}\, t^3 - 1.019613643364765.10^{-3}\, t^2 + 7.3638062870399326.10^{-2}\, t + 8.95 \quad (13)$$

- Stress equation

$$\sigma(t) = -1.3780465243551078.10^{-24}\, t^9 + 1.185256429710577.10^{-20}\, t^8 - 4.21454790060257.10^{-17}\, t^7 + 8.0723107479230814.10^{-14}\, t^6 - 9.1529600238167976.10^{-11}\, t^5 + 6.4149705415361.10^{-8}\, t^4 - 2.81935129602649.10^{-5}\, t^3 + 7.3526410139476139.10^{-3}\, t^2 - 0.843644849369\, t + 359.19 \quad (14)$$

Corrosion category C4

Standard ISO 12944-5 has defined the existence of this category, in coastal climatic and industrial zones with moderate salinity, chemical industry, shipbuilding, and vessels. In fig. 3.7 shows the relationship between the change in relative strain versus the action time of the corrosion category, and fig. 3.8 shows the relationship between the change in strength over time due to the corrosion effect of the category. Table 4 presents a result after processing by stochastic method and average method.

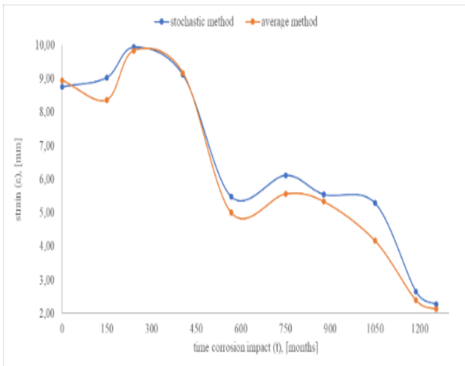


Fig: 3.7. Variation of the strain

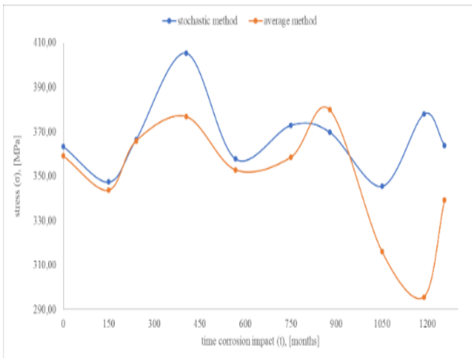


Fig: 3.8. Change in stress

Using the polynomial approximation [VIII-X] from fig. 3.7 and fig. 3.8, functional dependence for the strain and stress point in dependence of the time of the influence of the corrosion (in months) is established in equations (eq.15, eq.16, eq.17, and eq.18).

Table 4: Results after processing for the C4 category

time, [months]	Strain of lower yield point, ε, [mm]		Stress of lower yield point, σ, [MPa]	
	Stochastic method	Average method	Stochastic method	Average method
0	8.76	8.95	359.19	363.43
149	9.034	8.366	343.7	347.4
240	9.939	9.836	365.9	366.4
405	9.12	9.174	376.9	405.3
567	5.49	5.008	352.9	357.9
750	6.125	5.569	358.6	372.9
878	5.554	5.339	379.9	369.8
1050	5.295	4.173	316.1	345.5
1188	2.654	2.399	295.7	377.9
1256	2.274	2.132	339.4	363.9

Stochastic results

- Strain equation

$$\varepsilon(t) = 1.543301832191676.10^{-23} t^9 - 8.9519220758117541.10^{-20} t^8 + 2.1733287435017.10^{-16} t^7 - 2.8596270262743.10^{-13} t^6 + 2.2044988654785645.10^{-10} t^5 - 1.0035797215693892.10^{-7} t^4 + 2.5820600508053.10^{-5} t^3 - 3.37346209650047.10^{-3} t^2 + 1.7332965212903578.10^{-1} t + 8.76 \quad (15)$$

- Stress equation

$$\sigma(t) = 1.832605124195947.10^{-22} t^9 - 1.1413775472923909.10^{-18} t^8 + 2.9729585324060261.10^{-15} t^7 - 4.1946530743038878.10^{-12} t^6 + 3.467279374526266.10^{-9} t^5 - 1.692607951313438.10^{-6} t^4 + 4.65832735449761.10^{-4} t^3 - 6.395875440295087.10^{-2} t^2 + 3.24775325193426 t + 363.43 \quad (16)$$

Average results

- Strain equation

$$\varepsilon(t) = 1.2252135510445706.10^{-23} t^9 - 7.2187641668157365.10^{-20} t^8 + 1.778368631883912.10^{-16} t^7 - 2.3685925707139624.10^{-13} t^6 + 1.839238391163294.10^{-10} t^5 - 8.354934957846656410^{-8} t^4 + 2.1062677447774.10^{-5} t^3 - 2.6012128580769388.10^{-3} t^2 + 1.173363508689074.10^{-1} t + 8.95 \quad (17)$$

- Stress equation

$$\sigma(t) = -9.504620040850585.10^{-23} t^9 + 5.110694024930137.10^{-19} t^8 - 1.13624555698744.10^{-15} t^7 + 1.36095050882573.10^{-12} t^6 - 9.651571897579807.10^{-10} t^5 + 4.2310081389470598.10^{-7} t^4 - 1.1627795433348605.10^{-4} t^3 + 1.895098359574536.10^{-2} t^2 - 1.358379964545405 t + 359.19 \quad (18)$$

Corrosion category C5

Corrosive category C5 is determined by the ISO 12944-5 standard, to be applied in industrial areas with high humidity and aggressive environments. Buildings and areas with permanent condensation and pollution over 50% of pollution in cities. In fig. 3.9 shows the relationship between the change in relative strain versus the action time of the corrosion category, and Fig. 3.10 shows the relationship between the change in strength over time due to the corrosion effect of the category. Table 5 presents a result after processing by stochastic method and average method.

Table 5: Results after processing for C5 category

time, [months]	Strain of lower yield point, ε, [mm]		Stress of lower yield point, σ, [MPa]	
	Stochastic method	Average method	Stochastic method	Average method
0	8.76	8.95	359.19	363.43
59	9.034	8.366	343.7	347.4
96	9.939	9.836	365.9	366.4
162	9.12	9.174	376.9	405.3
227	5.49	5.008	352.9	357.9
300	6.125	5.569	358.6	372.9
351	5.554	5.339	379.9	369.8
420	5.295	4.173	316.1	345.5
475	2.654	2.399	295.7	377.9
502	2.274	2.132	339.4	363.9

Using the polynomial approximation [VIII-X] from fig. 3.9 and fig.3.10, functional dependence for the strain and stress point in dependence of the time of the influence of the corrosion (in months) is established in equations (eq.19, eq.20, eq.21, and eq.22).

Fig: 3.9. Variation of the strain

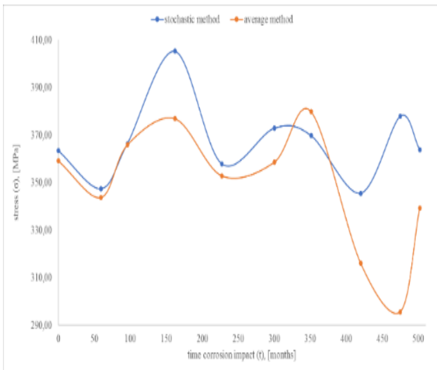


Fig: 3.10. Change in stress

Stochastic results

- Strain equation

$$\varepsilon(t) = 5.9013767496573117.10^{-20}\, t^9 - 1.3684558720025605.10^{-16}\, t^8 + 1.32815937387382.10^{-14}\, t^7 - 6.986151016155837.10^{-11}\, t^6 + 2.15291246721695.10^{-8}\, t^5 - 3.917604817868146.10^{-6}\, t^4 + 4.028181731073159.10^{-4}\, t^3 - 2.1024635027906.10^{-3}\, t^2 + 4.31279059704405.10^{-1}\, t + 8.76 \quad (19)$$

● Stress equation

$$\sigma (t) = 6.9548286941544253.10^{-19} t^9 - 1.7326841437103807.10^{-15} t^8 + 1.80513567966669.10^{-12} t^7 - 1.018585758113111.10^{-9} t^6 + 3.366686803922337.10^{-7} t^5 - 6.5701788587359136.10^{-5} t^4 + 7.225545178276475.10^{-3} t^3 - 3.9608021238996538.10^{-1} t^2 + 8.0154059884162265 t + 363.43 \quad (20)$$

Average results

● Strain equation

$$\varepsilon (t) = 4.6817842653253456.10^{-20} t^9 - 1.102894288038244.10^{-16} t^8 + 1.086371988175874.10^{-13} t^7 - 5.7856093965304.10^{-11} t^6 + 1.796457978920095.10^{-8} t^5 - 3.26334251004943.10^{-6} t^4 + 3.2899922731685.10^{-4} t^3 - 1.6249463597762175.10^{-2} t^2 + 2.9315929548303077.10^{-1} t + 8.95 \quad (21)$$

● Stress equation

$$\sigma (t) = -3.6271506728959245.10^{-19} t^9 + 7.796098494553348.10^{-15} t^8 - 6.926139485682052.10^{-13} t^7 + 3.313178752761348.10^{-10} t^6 - 9.3758941070114.10^{-8} t^5 + 1.638261261638271.10^{-5} t^4 - 1.7930088402156.10^{-3} t^3 + 1.164110073738766.10^{-1} t^2 - 3.3273950132025627 t + 359.19 \quad (22)$$

Corrosion category C6

The ISO 12944-5 standard has defined this category as a coastal zone with offshore installations and a high salt content. Buildings and structural facilities with a high degree of condensation and pollution over 75% of pollution in the chemical production of aggressive components. In fig. 3.11 shows the relationship between the change in relative strain versus the action time of the corrosion category and Fig. 3.12 shows the relationship between the change in strength over time due to the corrosion effect of the category. Table 6 presents a result after processing by stochastic method and average method.

Table 6: Results after processing for the CX category

time, [months]	Strain of lower yield point, ε, [mm]		Stress of lower yield point, σ, [MPa]	
	Stochastic method	Average method	Stochastic method	Average method
0	8.76	8.95	359.19	363.43
17	9.034	8.366	343.7	347.4
27	9.939	9.836	365.9	366.4
46	9.12	9.174	376.9	405.3
65	5.49	5.008	352.9	357.9
86	6.125	5.569	358.6	372.9
100	5.554	5.339	379.9	369.8
120	5.295	4.173	316.1	345.5
136	2.654	2.399	295.7	377.9
143	2.274	2.132	339.4	363.9

Using the polynomial approximation [VIII-X] from fig. 3.11 and fig. 3.12, functional dependence for the strain and stress point in dependence of the time of the influence of the corrosion (in months) is established in equations (eq.23, eq.24, eq.25, and eq.26).

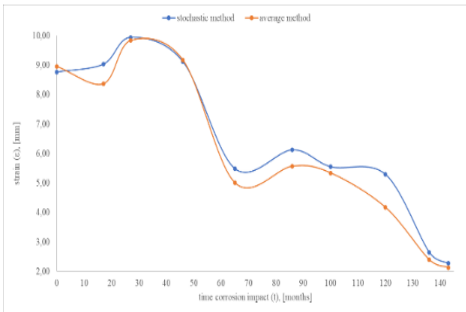


Fig: 3.11. Variation of the strain

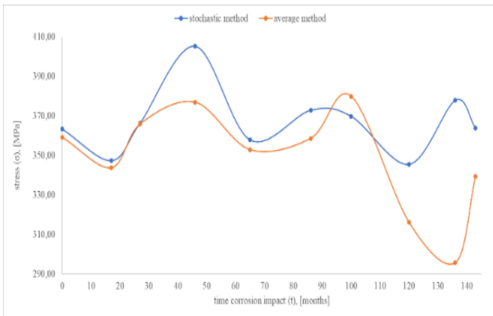


Fig: 3.12. Change in stress

Stochastic results

- Strain equation

$$\varepsilon(t) = 4.495855307765275.10^{-15}\, t^9 - 2.9715303207716067.10^{-12}\, t^8 + 8.2164761374770777.10^{-10}\, t^7 - 1.2304694326356146.10^{-7}\, t^6 + 1.078538507175318.10^{-5}\, t^5 - 5.574072196407944.10^{-4}\, t^4 + 1.62426055861719.10^{-2}\, t^3 - 2.3962530738507931.10^{-1}\, t^2 + 1.38942800511922\, t + 8.76 \quad (23)$$

- Stress equation

$$\sigma(t) = 5.1859047485918 66.10^{-14}\, t^9 - 3.6946436134164252.10^{-11}\, t^8 + 1.100020945672889.10^{-8}\, t^7 - 1.77253576945155.10^{-6}\, t^6 + 1.671380654365917.10^{-4}\, t^5 - 9.2920427274506973.10^{-3}\, t^4 + 2.9047558639397697.10^{-1}\, t^3 - 4.5099081586850129\, t^2 + 25.736251427109956\, t + 363.43 \quad (24)$$

Average results

- Strain equation

$$\varepsilon(t) = 3.481457032279549.10^{-15}\, t^9 - 2.3371535701614612.10^{-12}\, t^8 + 6.5559274053370015.10^{-10}\, t^7 - 9.9319886358636293.10^{-8}\, t^6 + 8.7572405978726993.10^{-6}\, t^5 - 4.50350508014586.10^{-4}\, t^4 + 1.27820719842285.10^{-2}\, t^3 - 1.759323053282189.10^{-1}\, t^2 + 0.86976088608913771\, t + 8.95 \quad (25)$$

- Stress equation

$$\sigma(t) = -3.0595472029860592.10^{-14}\, t^9 + 1.8985378271651068.10^{-11}\, t^8 - 4.8822061487597.10^{-8}\, t^7 + 6.781073367113724.10^{-7}\, t^6 - 5.5867022078063091.10^{-5}\, t^5 + 2.8404859501200566.10^{-3}\, t^4 - 8.970433471157449.10^{-2}\, t^3 + 1.652346194143302\, t^2 - 13.21825571394335\, t + 359.19 \quad (26)$$

The probability of results – stochastic results is 83.32 % and average results is 72.81 %. If I remove values from the formulas, I establish with sufficient practical accuracy, a basic non-linear equation [XIV], [XV], [XVI], [XVII] (eq. 27 and eq.28):

$$\varepsilon(t) = A_9.t^9 + A_8.t^8 + A_7.t^7 + A_6.t^6 + A_5.t^5 + A_4.t^4 + A_3.t^3 + A_2.t^2 + A_1.t + \varepsilon \quad (27)$$

Where: A_9, A_8, A_7, A_6, A_5, A_4, A_3, A_2, and A_1 are constant values and need to be determined experimentally in every case [VIII], [XI].

$$\sigma(t) = B_9.t^9 + B_8.t^8 + B_7.t^7 + B_6.t^6 + B_5.t^5 + B_4.t^4 + B_3.t^3 + B_2.t^2 + B_1.t + \sigma \quad (28)$$

Where: B_9, B_8, B_7, B_6, B_5, B_4, B_3, B_2, and B_1 are constant values and need to be determined experimentally in every case [VIII], [XI].

IV. Conclusion

This paper found that the change of lower yield point depending on the time of corrosion influence is not a linear function of the 9th degree with different coefficients. This result confirms the results known so far, that the change of values (strength and deformation) in the stress-strain curve on mechanical properties of steel with corrosion will follow a functional dependence of the 9th degree. In turn, this means that to predict with what values the calculations should be carried out, it is necessary to substitute into the established equations, which we can assume to be of sufficient accuracy for engineering practice. Establishing this type of dependence requires taking into account a variety of components and factors. It cannot be categorical that these established equations are universal, but rather for the specific type of steel i.e., S355JR. However, they make it possible to establish in time when the corroded steel member is expected to lose the relevant mechanical properties and brittle failure will occur. In practice, this can be used to establish the timing of repair activities and optimize the use of corroded steel structures. If a factor of safety greater than 1.35 is used, then the established equations can also be used for responsible steel structures (steel bridges, high-rise steel residential buildings, etc.).

Conflicts of Interest

The author declares that there are no conflicts of interest regarding the publication of this paper.

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